DEVELOPMENT OF A DATABASE FOR PRECAST WORKS' PRODUCTION RATES

ZAIRUL A'ZIYA BT ZULLEKFLI

BACHELOR OF ENGINEERING (HONS)
(CIVIL ENGINEERING)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

JANUARY 2008

DEVELOPMENT OF A DATABASE FOR PRECAST WORKS' PRODUCTION RATES

ZAIRUL A'ZIYA BT ZULLEKFLI

BACHELOR OF ENGINEERING (HONS)
(CIVIL ENGINEERING)
UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

JANUARY 2008

Development of a Database for Precast Works' Production Rates

By

Zairul A'ziya bt Zullekfli

Dissertation report submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

JANUARY 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Development of a Database for Precast Works' Production Rates

By

Zairul A'ziya bt Zullekfli

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

JANUARY 2008

Approved by,

____
(Assoc. Prof. Ir. Dr. Arazi Idrus)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2008

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

ZAIRUL A'ZIYA BT ZULKEFLI

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The objective of the research is to develop a reliable production rates database for precast construction works. It is due to no formal database for the production rates of precast construction in Malaysia. This research is mainly a starting point towards developing a new database in construction industry.

These projects will mainly focusing on three of the industrialized construction systems provided by CIDB that are precast concrete framing, panel and box system, precast steel framing system, precast block work system.

The main method used within the project is the Survey Research Method where questionnaires and interviews are the tools used in order to obtain the full information needed various respondents. Questionnaires designed based on its suitability with the respondent general needs and preference. The study sample is chosen as such, as it is rather convenient in terms of distance for the author to conducts research within that particular area and it is two of the most developing state in Malaysia. The research implemented in the project shall be in the form of survey research method, which utilized questionnaire and interview methods.

Questionnaire has been submitted to selected contractors and IBS manufacturer (by means of random sampling) located within Peninsular Malaysia and the responds received has been compiled and analyzed.

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge and thank everyone that has given me all the supports and guidance throughout the whole period of completing the final year project. Firstly, many thanks to the University and the Final Year Project coordinators that have coordinated and made the necessary arrangements especially in terms of the education on the final year project method and procedure.

I must also acknowledge the endless help and support received from my supervisor, AP. Ir. Dr. Arazi Idrus throughout the whole period of completing the final year project. His guidance and advises are very much appreciated. Apart from that, many thanks to Mr Saiful Nizam, the manager of Scrum Builders Sdn. Bhd for helping me in arranging interviews with him for the survey purposes. Apart from Mr Saiful, I must also thank Mr Kubenderan a/l Chandoran, a safety professional at BlueScope Lysagth (M) Sdn Bhd who was also former workers in Sunway Construction Sdn. Bhd that helped me a lot with this project.

I would also like to thank Mr Christiano for his endless support in terms of the discussion and opinions toward the process of this study. His continuous support and help throughout the whole period of survey are very much appreciated.

Finally, many thank to my fellow colleagues for their help and ideas throughout the completion of this study. Thank you all.

CHAPTER 1

INTRODUCTION

1.1. Background of Study

For this Final Year Project, the topic given is about the Development of a Database for Precast Construction Production Rates where the Project Management System played an important rule in achieving an optimum equivalence between time, cost and quality. Project management is about directing and coordinating human and material resources throughout the life of a project by using modern management techniques to achieve predetermined objectives of scope, cost, time and quality. The main objective of project management can be defined as to achieve an optimum equivalence between time, cost and quality.

Project Planning is the major subtopic in Project Management System which involves the choice of technology, the definition of work tasks, and the estimation of the required resources and durations for individual tasks and the identification of any interactions among the different work tasks. Project Planning can be divided to two categories which are the Cost Oriented and Schedule Oriented which respectively focusing on cost and time.

Planning of work schedule greatly relies on the availability of some fundamentals information such as the scope of work, sequence, quantity, production rates and ultimately durations of each works associated with the project. A specific calculation regarding production rates could not be completely derived through mathematical calculation. Thus one of the best methods in predicting accurate production rates would be to conduct surveys, over specific region by means of survey research methodology.

The Industrialized Building Systems (IBS) Roadmap 2003-2010 published by the Construction Industry Development Board (CIDB) outlines several well-thought strategies and aggressive steps to promote the use of IBS in Malaysia. The government is taking the leading role to persuade the construction industry to engage a more systematic approach and methodology in construction. It is a strategic change in the construction industry and the effort started in 1998.

Besides the aim to gradually reduce the dependency on foreign labor and saves the country from losing out foreign exchange, IBS provides the opportunity for the players in the construction industry to develop a new image of the construction industry to be at par with other manufacturing industries such as car and electronic industries. With the present conventional methods of construction, the industry is always associated with many unprofessional practices. The adoption of IBS promises to elevate every level of the industry to a new height and image of professionalism. By adopting IBS, efficient, clean, safe, professionally managed and handled by professionals and workers with relevant skills, proper coordination and management, precision, innovative and quality will be appeared as new attributes to be associated with the construction industry.

The industry players are expected to venture internationally and one of the pre-requisite to compete globally is to offer quality, efficient and professional services and again IBS can be an excellent option. Although some of IBS have been introduced in Malaysia as early as in 1960's, the industry as a whole seems quite reluctant to exploit the use of IBS. A recent survey carried out on the use of IBS in Malaysia reveals some of the issues and challenges, which require attention from different parties.

1.2. Problem Statement

1.2.1. Problem Identification

1. No formal database for Malaysian construction production rates published by any authorities.
2. Construction rates still not available in our industry.
3. Project planners mostly rely on individual experience and estimation in deriving the production rates values.

4. Specific calculation could not be derived to calculate the accurate values of construction production rates due to its affect by various factors.

1.2.2. Significance of the Project

This project could overcome the problems in our industry as the project would help in the development of more reliable production rates database, thus decreasing the margin of errors in estimating the relevant production rates for industrialized construction works.

Besides that, this project will encourage engineers to use the pre-cast system (IBS) for their construction purpose in the future. It also will make all construction people to realize the important and benefit of IBS system as campaigned by CIDB.

This particular information gathered from my project would be incorporated with the production rates value, thus enabling the estimators to get a correct rough idea on the significance of the values produced by the project.

Although the project's scope is quite limited (Peninsular Malaysia), the project could be a basis and being further developed through times for the benefit of Malaysian Construction Industry.

1.3. Objectives and Scope of Study

1.3.1. Objectives

The objectives of this project are as follow:

1. To identify the sequence of activities in IBS system at site (sample building).
2. To collect, compile and analyze the production rates' values from the industry.

3. To develop a database based and analysis of data collected from survey and other sources such as planning plant, public literature, expert interview and questionnaire.

1.3.2. Scope of Study

The study shall focus on production rates for three main pre-cast works which are:

1. Pre-cast Concrete Framing, Panel and Box System
2. Pre-cast Steel Framing System
3. Pre-cast Block Work System

Questionnaire surveys shall be submitted to construction firms located within Peninsular Malaysia. The number of construction firms shall be decided through methods of sampling calculation.

Due to lack of time and insignificant data from the survey conducted, the analysis of the result will focus mainly on Precast Concrete Framing, Panel and Box System.

CHAPTER 2

LITERATURE REVIEW

2.1. Production Rates

Production rates could be defined as the amount of works that could be done within a certain period of time. It is one of the most essential information used in scheduling works to determine the duration for specified construction works. Production rates' values are influenced by several factors such as climate, geography, man power and technology applied during construction. The variation of the factors could not be totally controlled, thus producing different values of production rates in every project. However, a basic theory in calculating production rates could be derived by methods shown below.

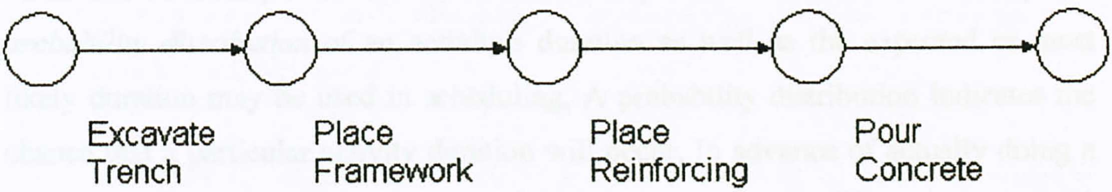


Figure 2.1: Illustrative Set of Four Activities with Precedence

According to Baker (1974)

The scheduling problem is to determine an appropriate set of activity start time, resource allocations and completion times that will result in completion of the project in a timely and efficient fashion. Construction planning is the necessary fore-runner to scheduling. In this planning, defining work tasks, technology and construction method is typically done either simultaneously or in a series of iterations. (p. 15)

In most scheduling procedures, each work activity has associated time duration. These durations are used extensively in preparing a schedule. For example, suppose that the durations shown in Table 2.1 were estimated for the project diagrammed in Figure 2.1. The entire set of activities would then require at least 3 days, since the activities follow one another directly and require a total of 1.0 + 0.5 + 0.5 + 1.0 = 3 days. If another activity proceeded in *parallel* with this sequence, the 3 day minimum duration of these four activities is unaffected. More than 3 days would be required for the sequence if there was a delay or a lag between the completion of one activity and the start of another.

Table 2.1: Durations and predecessors for a Four Activity Project illustration

Activity	Predecessor	Duration (Days)
Excavate Trench	-	1.0
Place Formwork	Excavate Trench	0.5
Place Reinforcement	Place Formwork	0.5
Pour Concrete	Place Reinforcement	1.0

All formal scheduling procedures rely upon estimates of the durations of the various project activities as well as the definitions of the predecessor relationships among tasks. The variability of an activity's duration may also be considered. Formally, the *probability distribution* of an activity's duration as well as the expected or most likely duration may be used in scheduling. A probability distribution indicates the chance that a particular activity duration will occur. In advance of actually doing a particular task, we cannot be certain exactly how long the task will require.

A straightforward approach to the estimation of activity durations is to keep historical records of particular activities and rely on the average durations from this experience in making new duration estimates. Since the scopes of activities are unlikely to be identical between different projects, unit productivity rates are typically employed for this purpose. For example, the duration of an activity D_{ij} such as concrete formwork assembly might be estimated as:

(1) $$D_{ij} = \frac{A_{ij}}{P_{ij} N_{ij}}$$

where A_{ij} is the required formwork area to assemble (in square yards), P_{ij} is the average productivity of a standard crew in this task (measured in square yards per hour), and N_{ij} is the number of crews assigned to the task. In some organizations, unit production time, T_{ij}, is defined as the time required to complete a unit of work by a standard crew (measured in hours per square yards) is used as a productivity measure such that T_{ij} is a reciprocal of P_{ij}.

A formula such as Eq. (1) can be used for nearly all construction activities. Typically, the required quantity of work, A_{ij} is determined from detailed examination of the final facility design. This *quantity-take-off* to obtain the required amounts of materials, volumes, and areas is a very common process in bid preparation by contractors. In some countries, specialized quantity surveyors provide the information on required quantities for all potential contractors and the owner. The number of crews working, Nij, is decided by the planner. In many cases, the number or amount of resources applied to particular activities may be modified in light of the resulting project plan and schedule. Finally, some estimate of the expected work productivity, Pij must be provided to apply Equation (1). As with cost factors, commercial services can provide average productivity figures for many standard activities of this sort. Historical records in a firm can also provide data for estimation of productivities.

The calculation of a duration as in Equation (1) is only an approximation to the actual activity duration for a number of reasons. First, it is usually the case that peculiarities of the project make the accomplishment of a particular activity more or less difficult. For example, access to the forms in a particular location may be difficult; as a result, the productivity of assembling forms may be lower than the average value for a particular project. Often, adjustments based on engineering judgment are made to the calculated durations from Equation (1) for this reason.

In addition, productivity rates may vary in both systematic and random fashions from the average. An example of systematic variation is the effect of learning on productivity. As a crew becomes familiar with an activity and the work habits of the crew, their productivity will typically improve. Figure 2.2 illustrates the type of productivity increase that might occur with experience; this curve is called a learning curve. The result is that productivity Pij is a function of the duration of an activity or project. A common construction example is that the assembly of floors in a building might go faster at higher levels due to improved productivity even though the transportation time up to the active construction area is longer. Again, historical records or subjective adjustments might be made to represent learning curve variations in average productivity. 'Hendrickson, Martinelli, Rehak (1987)'

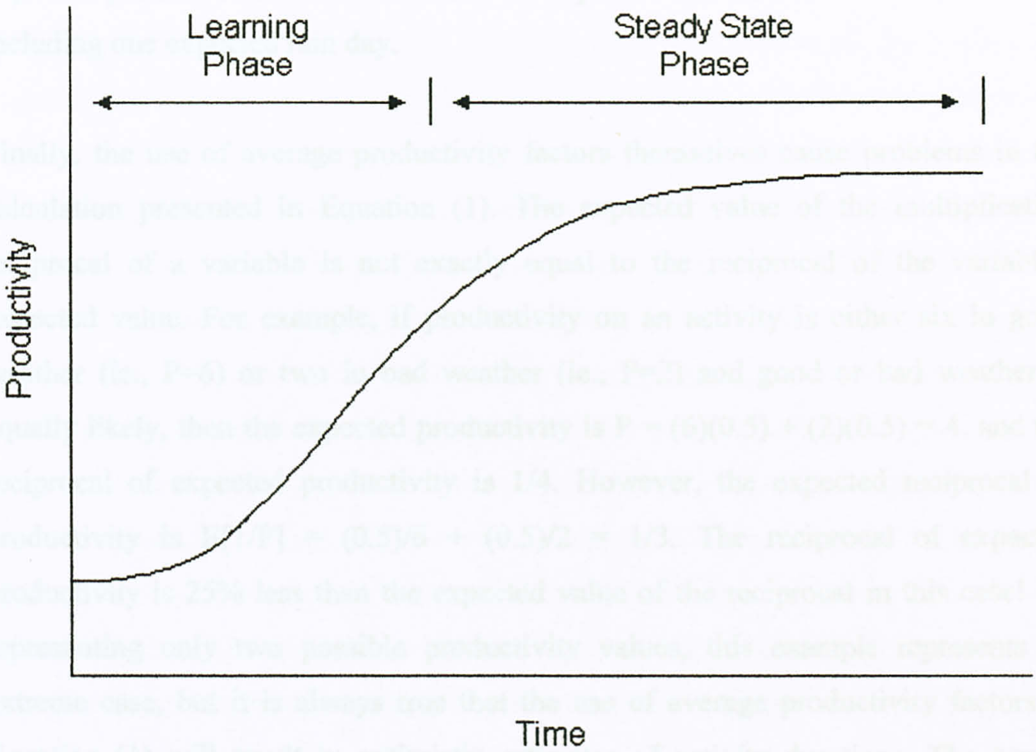


Figure 2.2: Illustration of Productivity Changes Due to Learning

Random factors will also influence productivity rates and make estimation of activity durations uncertain. For example, a scheduler will typically not know at the time of making the initial schedule how skillful the crew and manager will be that are assigned to a particular project. The productivity of a skilled designer may be many times that of an unskilled engineer. In the absence of specific knowledge, the estimator can only use average values of productivity.

Weather effects are often very important and thus deserve particular attention in estimating durations. Weather has both systematic and random influences on activity durations. Whether or not a rainstorm will come on a particular day is certainly a random effect that will influence the productivity of many activities. However, the likelihood of a rainstorm is likely to vary systematically from one month or one site to the next. Adjustment factors for inclement weather as well as meteorological records can be used to incorporate the effects of weather on durations. As a simple example, an activity might require ten days in perfect weather, but the activity could not proceed in the rain. Furthermore, suppose that rain is expected ten percent of the days in a particular month. In this case, the expected activity duration is eleven days including one expected rain day.

Finally, the use of average productivity factors themselves cause problems in the calculation presented in Equation (1). The expected value of the multiplicative reciprocal of a variable is not exactly equal to the reciprocal of the variable's expected value. For example, if productivity on an activity is either six in good weather (ie., P=6) or two in bad weather (ie., P=2) and good or bad weather is equally likely, then the expected productivity is P = (6)(0.5) + (2)(0.5) = 4, and the reciprocal of expected productivity is 1/4. However, the expected reciprocal of productivity is E[1/P] = (0.5)/6 + (0.5)/2 = 1/3. The reciprocal of expected productivity is 25% less than the expected value of the reciprocal in this case! By representing only two possible productivity values, this example represents an extreme case, but it is always true that the use of average productivity factors in Equation (1) will result in optimistic estimates of activity durations. The use of actual averages for the reciprocals of productivity or small adjustment factors may be used to correct for this non-linearity problem.

The simple duration calculation shown in Equation (1) also assumes an inverse linear relationship between the number of crews assigned to an activity and the total duration of work. While this is a reasonable assumption in situations for which crews can work independently and require no special coordination, it need not always be true. For example, design tasks may be divided among numerous architects and engineers, but delays to insure proper coordination and communication increase as the number of workers increase. As another example, insuring a smooth flow of material to all crews on a site may be increasingly difficult as the number of crews increase. In these latter cases, the relationship between activity duration and the number of crews is unlikely to be inversely proportional as shown in Equation (1). As a result, adjustments to the estimated productivity from Equation (1) must be made. Alternatively, more complicated functional relationships might be estimated between duration and resources used in the same way that nonlinear preliminary or conceptual cost estimate models are prepared.

One mechanism to formalize the estimation of activity durations is to employ a hierarchical estimation framework. This approach decomposes the estimation problem into component parts in which the higher levels in the hierarchy represent attributes which depend upon the details of lower level adjustments and calculations. For example, Figure 2.3 represents various levels in the estimation of the duration of masonry construction. According to Thomas, Matthews, Ward (1986), at the lowest level, the maximum productivity for the activity is estimated based upon general work conditions. Table 2.2 illustrates some possible maximum productivity values that might be employed in this estimation. At the next higher level, adjustments to these maximum productivities are made to account for special site conditions and crew compositions; Table 2.3 illustrates some possible adjustment rules. At the highest level, adjustments for overall effects such as weather are introduced. The formalization of the estimation process illustrated in Figure 2.1(c) permits the development of computer aids for the estimation process or can serve as a conceptual framework for a human estimator.

TABLE 2.2 Maximum Productivity Estimates for Masonry Work

Masonry unit size	**Condition(s)**	**Maximum Productivity Achievable**
8 inch block	None	400 units/day/mason
6 inch	Wall is "long"	430 units/day/mason
6 inch	Wall is not "long"	370 units/day/mason
12 inch	Labor is nonunion	300 units/day/mason
4 inch	Wall is "long" Weather is "warm and dry" or high-strength mortar is used	480 units/day/mason
4 inch	Wall is not "long" Weather is "warm and dry" or high-strength mortar is used	430 units/day/mason

4 inch	Wall is "long" Weather is not "warm and dry" or high-strength mortar is not used	370 units/day/mason
4 inch	Wall is not "long" Weather is not "warm and dry" or high-strength mortar is not used	320 units/day/mason
8 inch	There is support from existing wall	1,000 units/day/mason
8 inch	There is no support from existing wall	750 units/day/mason
12 inch	There is support from existing wall	700 units/day/mason
12 inch	There is no support from existing wall	550

TABLE 2.3 Possible Adjustments to Maximum Productivities for Masonry Construction.

Impact	Condition(s)	Adjustment magnitude (% of maximum)
Crew type	Crew type is nonunion Job is "large"	15%
Crew type	Crew type is union Job is "small"	10%
Supporting labor	There are less than two laborers per crew	20%
Supporting labor	There are more than two masons/laborers	10%
Elevation	Steel frame building with masonry exterior wall has "insufficient" support labor	10%

Elevation	Solid masonry building with work on exterior uses nonunion labor	12%
Visibility	block is not covered	7%
Temperature	Temperature is below 45° F	15%
Temperature	Temperature is above 45° F	10%
Brick texture	bricks are baked high Weather is cold or moist	10%

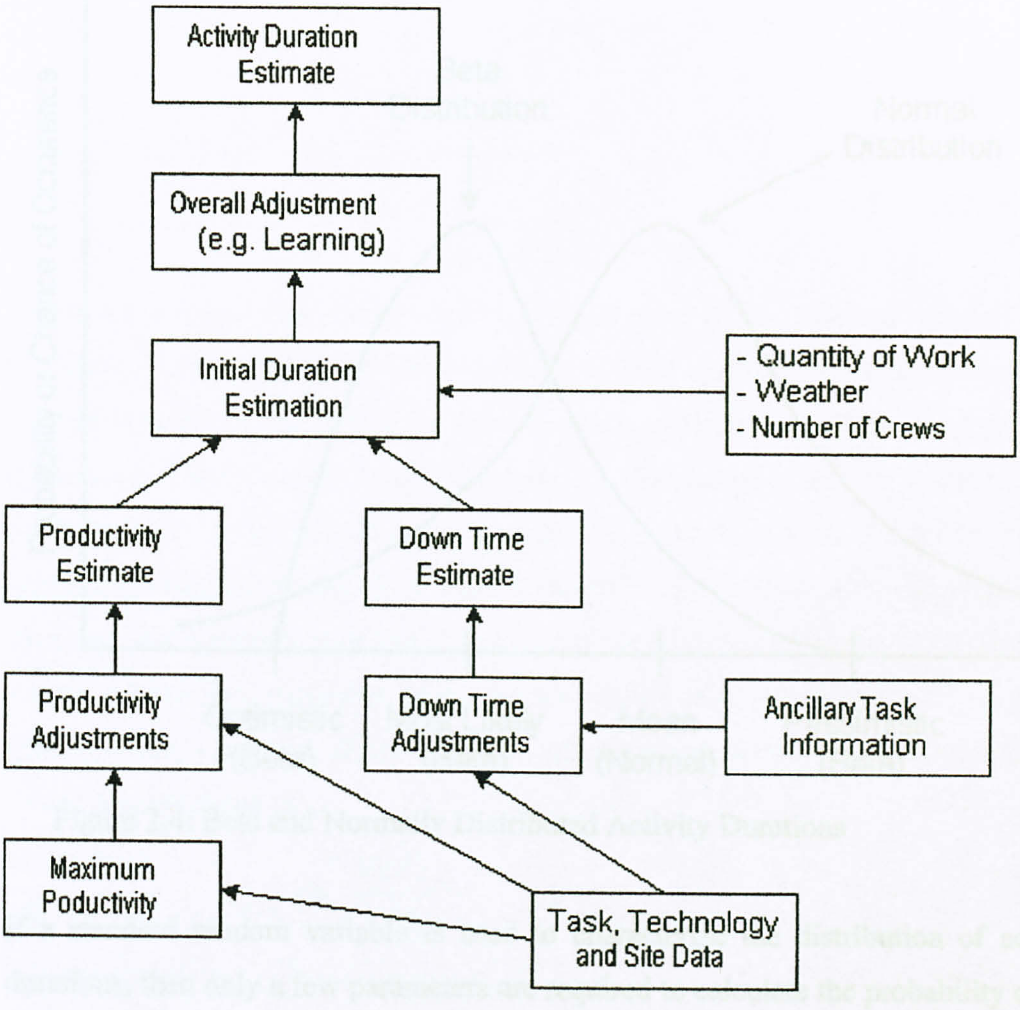


Figure 2.3: A Hierarchical Estimation Framework for Masonry Construction

In addition to the problem of estimating the expected duration of an activity, some scheduling procedures explicitly consider the uncertainty in activity duration estimates by using the probabilistic distribution of activity durations. That is, the duration of a particular activity is assumed to be a random variable that is distributed in a particular fashion. For example, an activity duration might be assumed to be distributed as a normal or a beta distributed random variable as illustrated in Figure 2.4. This figure shows the probability or chance of experiencing a particular activity duration based on a probabilistic distribution. The beta distribution is often used to characterize activity durations, since it can have an absolute minimum and an absolute maximum of possible duration times. The normal distribution is a good approximation to the beta distribution in the center of the distribution and is easy to work with, so it is often used as an approximation.

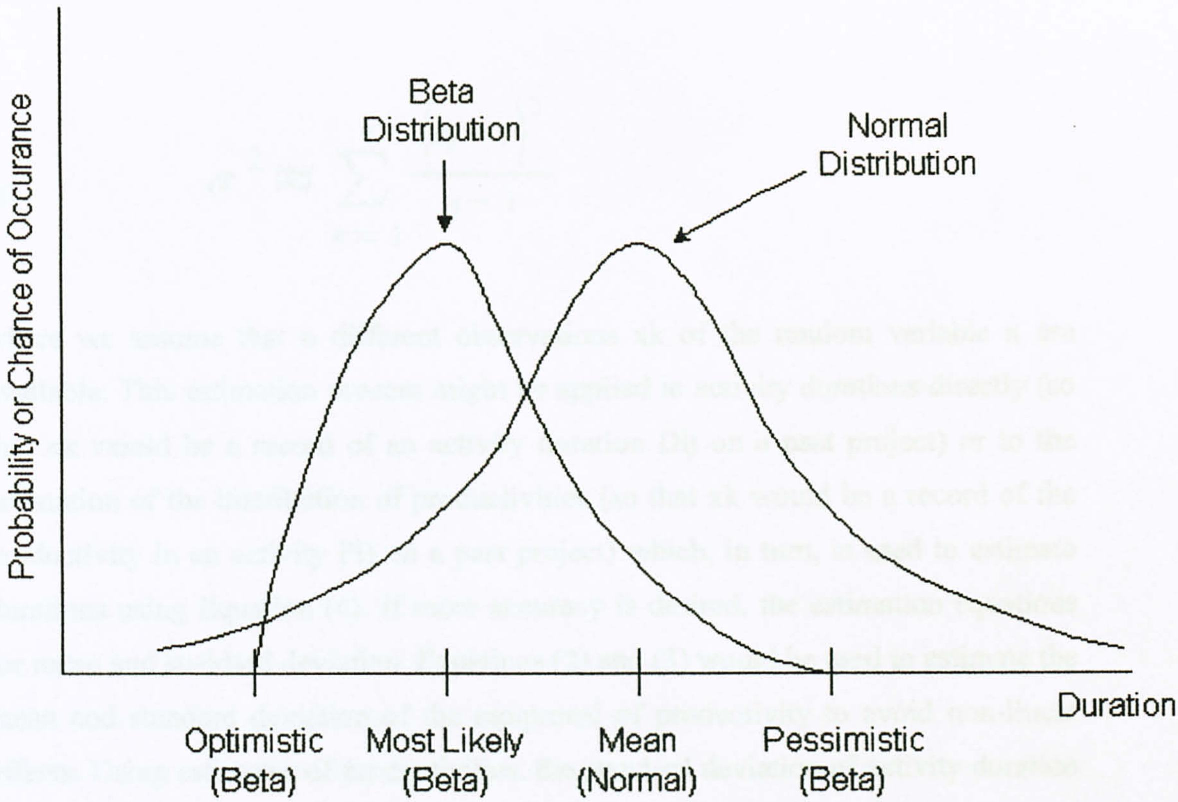


Figure 2.4: Beta and Normally Distributed Activity Durations

If a standard random variable is used to characterize the distribution of activity durations, then only a few parameters are required to calculate the probability of any particular duration. Still, the estimation problem is increased considerably since more than one parameter is required to characterize most of the probabilistic distribution used to represent activity durations. For the beta distribution, three or four parameters are required depending on its generality, whereas the normal distribution requires two parameters.

As an example, the normal distribution is characterized by two parameters, μ and σ representing the average duration and the standard deviation of the duration, respectively. Alternatively, the variance of the distribution σ^2 could be used to describe or characterize the variability of duration times; the variance is the value of the standard deviation multiplied by itself. From historical data, these two parameters can be estimated as:

(2) $$\mu \approx \bar{x} = \sum_{k=1}^{n} \frac{x_k}{n}$$

(3) $$\sigma^2 \approx \sum_{k=1}^{n} \frac{\left(x_k - \bar{x}\right)^2}{n-1}$$

where we assume that n different observations xk of the random variable x are available. This estimation process might be applied to activity durations directly (so that xk would be a record of an activity duration Dij on a past project) or to the estimation of the distribution of productivities (so that xk would be a record of the productivity in an activity Pi) on a past project) which, in turn, is used to estimate durations using Equation (4). If more accuracy is desired, the estimation equations for mean and standard deviation, Equations (2) and (3) would be used to estimate the mean and standard deviation of the reciprocal of productivity to avoid non-linear effects. Using estimates of productivities, the standard deviation of activity duration would be calculated as:

(4) $$\sigma_{ij} \approx \frac{A_{ij}\sigma_{1/P}}{N_{ij}}$$

where $\sigma_{1/P}$ is the estimated standard deviation of the reciprocal of productivity that is calculated from Equation (3) by substituting 1/P for x.

2.2. Precast System / Industrialised Building System

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. The manufacturing of the components is systematically done using machine, formworks and other forms of mechanical equipment. The components are manufactured offsite and once completed will be delivered to construction sites for assembly and erection.

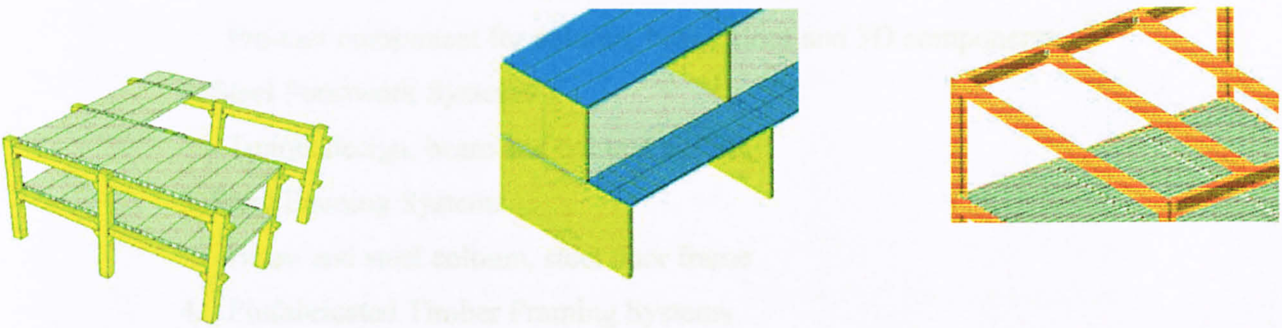


Figure 2.5: (a). Skeletal precast concrete framed structure (b). Precast concrete Wall (c). Steel framed structure
Sources: Ahmad Baharuddin (2006)

According to Ahmad Baharuddin (2006), the IBS systems as mentioned above are not new in Malaysia. For example, precast wall system has been adopted in Malaysia as early as in the late 60s. Even though the IBS systems have been in existence for a long time but there are still many unresolved issues. Some of the issues are the ability of the industry players to equip with necessary technical knowledge in order to adopt IBS in their projects. Examples of this lacking are clearly reflected in the quality of the completed projects and there are situations where IBS could not be continued due to unavailability of relevant technical experts. This paper discusses those issues and suggests appropriate approach in overcoming them.

The average person likely is unaware of the presence of the hidden systems that make life what it is today: civilized. Sanitary and storm sewers, box culverts, catch basins, pump/lift stations, septic tanks, exterior grease interceptors, water storage tanks, wet wells, electrical and communication vaults and many other products all play a pivotal role in maintaining a clean, healthy, productive environment for the inhabitants of the civilized world.

Without these systems, life would be much different. Much of the credit can be given to the main components of these systems, which typically consist of precast construction. From the structure classification, IBS can be divided into five major groups which are:

1. Pre-cast Concrete Framing, Panel and Box System

   Pre-cast component for column, beam, floor and 3D components

2. Steel Formwork Systems

   Tunnel design, beam and column casting

3. Steel Framing Systems

   Beam and steel column, steel door frame

4. Prefabricated Timber Framing Systems

   Timber frame, timber roof

5. Block Work System

   Concrete Masonry Unit (CMU), light weight block

According to Kim S. Elliott, 2002 the implementation of IBS gives benefits in reducing the use of general worker, minimizing wastage and controlling the quality to be more effectives. There were a few high class contractors that choose IBS for their important project such as PETRONAS Twin Tower, Putrajaya, KL Central and KLIA.

For this project, author will only concentrate on three main IBS's groups which are Pre-cast Concrete Framing, Panel and Box System, Precast Steel Framing System and Block Work System.

2.3. Estimating Production Rate (based on previous related work)

According to Samer Ezeldin and Lokman (2006)

To estimate the cost of a construction, it is important to determine the quantities of works to be completed and the associated cost involved. There are two method of cost determination which is unit pricing and resource enumeration (Halpin and Wood head 1998).

For the unit pricing approach, the unit cost (dollar/unit) was applied to the quantity of the item in order to obtain the amount of work at hand. For a given items, the unit costs were usually tabulated within a company or in standard references as an average reflecting performance on a multitude of projects.

Compare to the unit pricing method, the resource enumeration method is more detailed. A resource group (crew, equipment etc) for a given item has to be assume, cost per hour for the assumed resource group need to be calculated, its average production has to be estimate and then it has to be modify to reflect job efficiency.

These rates are normally tabulated as average values reflecting average conditions for a given project. The estimator will start it by calculating the average production rates and modifies it to reflect the conditions expected to be encountered on a specific project being estimated.

For an experienced estimator, they will rely on their personal expertise to incorporate the effect of qualitative factors in their estimates but for less/non experienced estimator, the neural networks could benefit them. The neural networks are tools that attempt to mimic the human brain function. Portas and Abourizk (1997) designed a system that utilizes artificial neural networks to estimate formwork productivity for slabs, columns and walls. Chao and Skibniewski (1993) used neural network as a case study to predict the productivity of an excavator.

In order to achieve the objectives of the construction project, a systematic methodology had to be implemented and followed. Having the factors that could impact the construction production rate, actual data are required. Collecting actual data involves two stages which are organizing data that existed in project files or company data base and the second stage involved collecting information by using survey method.

To develop an initial survey form, literature was first used includes the factors that effect the productivity rates of a construction project (Chao and Skibniewski 1994; Halligan et al. 1994; Ersoz 1999). This initial survey form will be discussed during an interview conducted with personal interviewers in different types of construction background. This procedure was conducted in order to gained variety information on the project based on the survey form (refer figure 2.6).

Data gained by the questionnaires received from survey process are considered to be independent variable, while multiplier is the dependent variable. It is for the purposes of conducting the statistical analysis. All data was assessed by using correlation and scatter plot and through building regression models.

Neural network is used to learn the relationships between data. This process is referring as training. The neural network can be used after been trained to solve similar problems to the ones it was trained on (a process referred to as recall). Neural network are composed of processing elements PE (represent graphically by circles) and connections (represented by arrows) as demonstrated in Fig. 2.7. Input factors like factors that are thought to affect labor production are represented by the input layer. While the output factors were represented as the output layer.

This network can be used for classification or prediction. For classification networks, the network will be thought in how to group the data into a number of classes based on the input provided to it. A comprehensive overview of neural networks can be found in Flood and Kartan (1994a,b).

The neural network structure utilize in this application represent an extension to the network approach describe by Portas and Abourizk (1998). This output is represented in the form of a histogram reflecting the likelihood of the production rate rather than a single point estimate. The user of the network has the opportunity to make a subjective decision regarding the rate to be use or by using the weighted average of the rates given by the histogram

Survey on concrete work productivity

The purpose of this survey is to asses the productivity of concrete works putting in consideration various factors and conditions that may affect this productivity.

Principal Data

Form filled by ________________ Position ________________
Company ________________ Date of Survey ________________

Project Data

Project Name ________________ Owner ________________
Project Location ________________ Consultant ________________
Project Description ________________ Contractor ________________

General Data

Structural Element(s) Under Consideration ________________
Quantity of Concrete ________________ m3
Duration of the construction (formwork, steel fixing & concrete Pouring) ________________ days

Temperature Conditions	0 Cold	0 Moderate	0 Hot
Working Condition	0 Mild	0 Moderate	0 Harsh

Formwork Assembly data

Crew size ______ no Duration ________ days
Type of formwork ____________ Type of false work ____________

How do you classify the supervision over the labor?	0 little	0 adequate	0 strict
How do you classify the labor skill	0 unskillful	0 adequate	0 skillful
Did labor stay overtime significantly	0 yes	0 no	
Complexity of the task	0 typical	0 complex	
Accessibility of Materials	0 easy	0 moderate	0 hard
Degree of repetition	0 none	0 moderate	0 repetitive

Steel Fixing Data

Crew size ________________ no Duration ________________ no
Quantity ________________ tons

How do you classify the supervision over the labor	0 little	0 adequate	0 strict
How do you classify labor skill	0 unskillful	0 moderate	0 skillful
Did labor stay overtime significantly	0 yes	0 no	
Complexity of the task	0 typical	0 complex	
Accessibility of Materials	0 easy	0 moderate	0 hard
Degree of repetition	0 none	0 moderate	0 repetitive

Concrete Pouring

Pouring Crew Size ________________ no Duration ________________ no

What type of pouring method was used	0 ready mix	0 batch plant	0 traditional mixer
Did labor stay overtime significantly	0 yes	0 no	
Complexity of the task	0 typical	0 complex	
Accessibility of Materials	0 easy	0 moderate	0 hard
Degree of repetition	0 none	0 moderate	0 repetitive

General Comments

Figure 2.6. Survey form of productivity of concrete works

Source: Samer Ezeldin and Lokman (2006)

The most important aspect of neural network in a practical application within an industrial setting are defining input factor and collecting sufficient relevant data for training. It is best to achieve the first aspect by using person that are familiar to the environment while for the second aspect, it is best to accomplished it by designing statistical experiment and by obtaining a real commitment from those that posses information and knowledge in how to retrieve it or to use it.

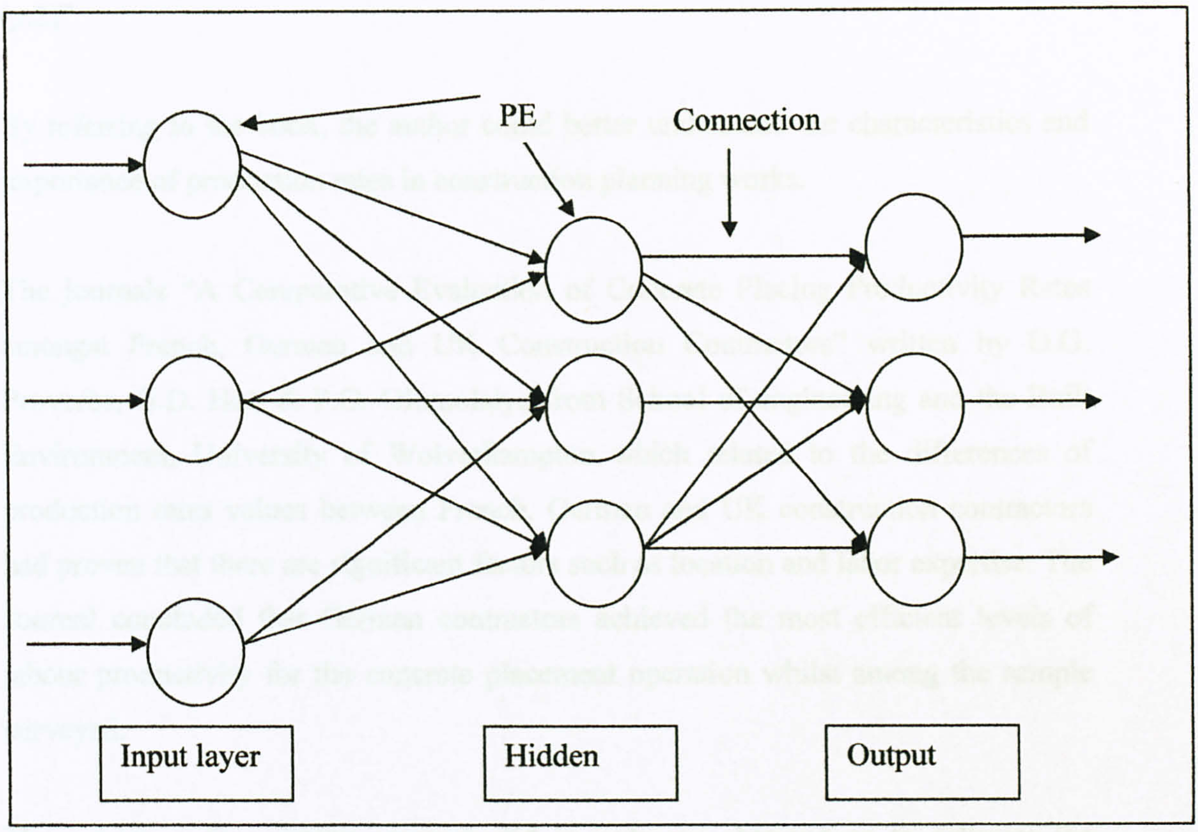


Figure 2.7. Sample Three-Layer Back-Propagation Neural Network

Sourced: Abourizk, Knowles and Hermann (2001)

2.4. Previous Related Studies

Throughout this study, most of the books related to the production rates topic are done by foreign researchers. Little works has been done by local researchers regarding this topic. Basically, most of the theory and basic idea in this study have been established by referring to the foreign researchers' journals and books. One of the books that have been thoroughly used in this study is the book written by Chris Hendrickson, the 'Fundamental Concepts for Owners, Engineers, Architects and

Builders' which covers topics such as construction planning, fundamental scheduling procedures and advance scheduling techniques. (Chris Hendrickson (1989)).

"Productivity improvements are always of importance and value. As a result, introducing new materials and automated construction processes is always desirable as long as they are less expensive and are consistent with desired performance. (p.2)"

By referring to the book, the author could better understand the characteristics and importance of production rates in construction planning works.

The journals "A Comparative Evaluation of Concrete Placing Productivity Rates amongst French, German and UK Construction Contractors" written by D.G. Proverbs, G.D. Holt & P.O. Olomolaiye from School of engineering and the Built Environment, University of Wolverhampton which related to the differences of production rates values between French, German and UK construction contractors had proven that there are significant factors such as location and labor expertise. The Journal concluded that German contractors achieved the most efficient levels of labour productivity for the concrete placement operation whilst among the sample surveyed.

There were a few similar research did in order to obtained or to estimate the productivity rates of a specific construction work in the construction industry such as:

1. Estimating Labor Production Rates For Industrial Construction Activities
   By S. AbouRizk, P. Knowles and U.R. Hermann
2. Neural Networks for Estimating The Productivity of Concreting Activities
   By A. Samer Ezeldin and Lok,am M. Sharara
3. Crew Production Rates for Contract Time Estimation : Beam Erection, Deck and Rail of Highway Bridges.
   By James T. O'Connor M.ASCE and Youngki Huh
4. Effects of Delay Times on Production Rates in Construction

By John Christian and Daniel Hachey

This project will also receive consultation from CIDB research unit as a moment, there is no institution that has conducting the research. CIDB was just about to approve the research grand for any researches involve in this area. We are hoping that by doing this research, there will be a better chance for UTP to be award with the grand letter.

CHAPTER 3
METHODOLOGY

3.1. Survey Design

The study will over the whole construction level in Peninsular Malaysia and will implement survey research method which incorporates tools such as questionnaire and interview in order to obtain the production rates stated above.

Questionnaire surveys shall be submitted to construction firms mainly in Peninsular Malaysia included lists from CIDB directory. For a start, a minimum no of 120 samples delivered to the pre-cast contractors, pre-cast manufactories and major main contractor of class A & B. The questionnaire will also covers information related to production rates such as number of workers, area of construction, climates and technology implemented in the construction.

3.2. Survey Questionnaire Process

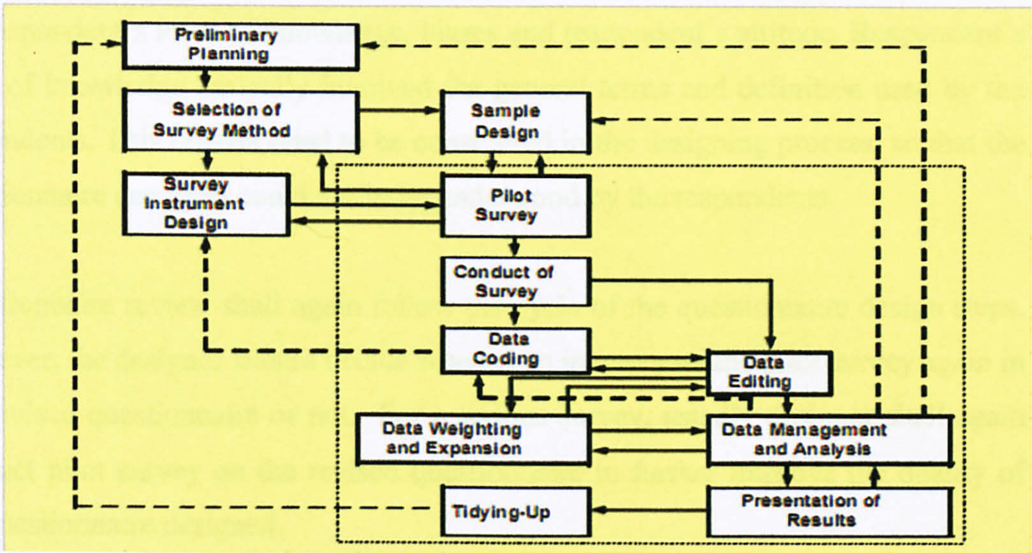


Figure 3.1: Flow Chart for Questionnaire Process

Source: Cooper, Donal and Schindler (2003)

<u>Literature Review & Research:</u>

Literature review is an important process in the project, as it provides the author with the general idea on the project. The methodologies involved in this process are mainly research on internet, library and discussion with Supervisor and Tutor.

Journal is a very useful source of information to the author because it has stated the previous research done by other researchers about the topic. Furthermore, the references provided in the journal are much important for the author to look for other reliable sources of information

Survey / Questionnaire Design:

Generally, the process in designing a questionnaire could be divided into 3 major steps which are considerations & rule of thumb, pilot survey and questionnaire revisions. The methodology in considering the considerations and rule of thumbs in designing the questionnaire are generally adopted by literature review and research. Questionnaire revision is one of the steps, carried out after the pilot survey in order to further enhance the questionnaires from various aspects.

In designing the questionnaire, several considerations need to be considered such as the respondent's level of knowledge, biases and respondent's attitude. Respondent's level of knowledge basically involved the general terms and definition used by the respondents. This criteria need to be considered in the designing process, so that the questionnaire designed could easily be understood by the respondents.

Questionnaire review shall again follow the cycle of the questionnaire design steps. However, the designer should decide whether to incorporate the pilot survey again in the revised questionnaire or not. For a serious survey, usually designer shall again conduct pilot survey on the revised questionnaire to further improve the quality of the questionnaire designed.

There are nine (9) basic procedures in developing a questionnaire:

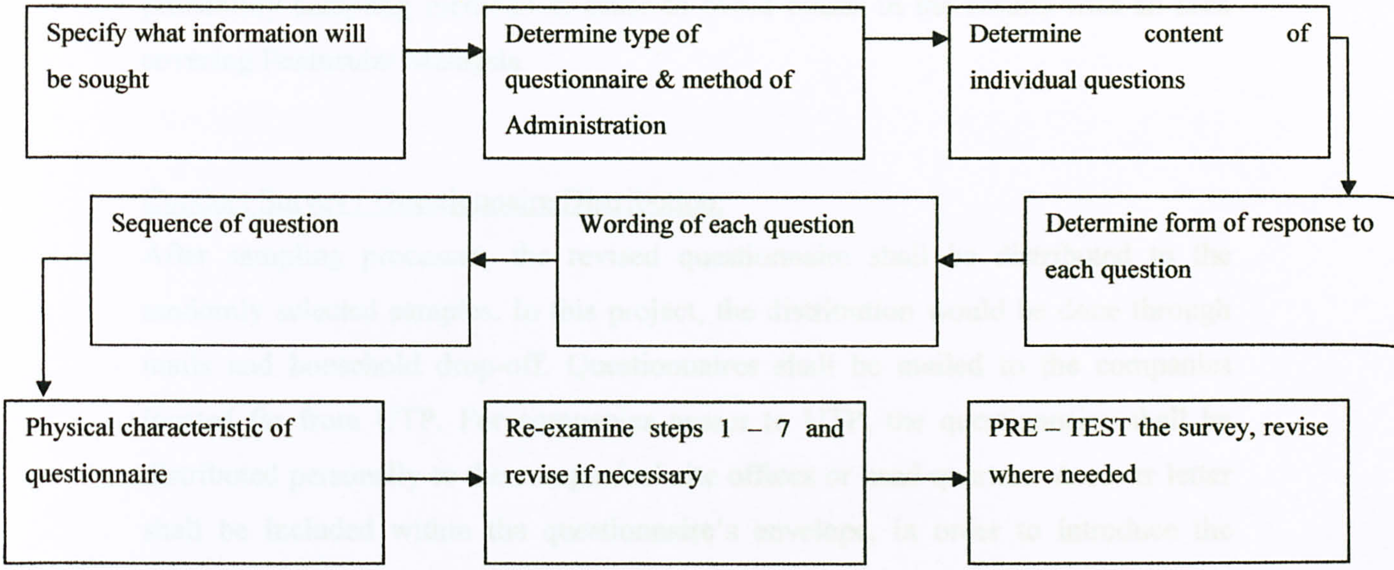


Figure 3.2: Questionnaire developing procedure chart

<u>Pilot Survey:</u>

Pilot survey shall be conducted after the final draft of the questionnaire has been completed. The pilot survey shall be conducted both internally and externally. Three internal respondents (UTP's lecturer) and three external respondents (contractor) shall be chosen randomly for the survey. The respondents shall be given a period of time to complete the questionnaire. The questionnaire will then be collected to be analyzed.

A pilot survey is a test of all aspects of design which act like a live dress rehearsal. It consists of some scopes for experimental design. By conducting the pilot survey, it could save few of expensive mistakes. Pilot survey are use to test the wording of questionnaire and also the layout of questionnaire.

<u>Sampling:</u>

There are two different types of sampling procedures--probability and non probability. Probability sampling methods ensure that there is a possibility for each person in a sample population to be selected, whereas non probability methods target specific individuals. The project shall implement a probability sampling methods in order to avoid biases in the results with an area covering Peninsular Malaysia

<u>Conduct Survey / Questionnaire Distribution:</u>

After sampling processes, the revised questionnaire shall be distributed to the randomly selected samples. In this project, the distribution would be done through mails and household drop-off. Questionnaires shall be mailed to the companies located far from UTP. For companies nearer to UTP, the questionnaire shall be distributed personally to the companies' site offices or head quarters. A cover letter shall be included within the questionnaire's envelope, in order to introduce the project to the respondents.

1. Mail Survey

   After questionnaire fabrication, the questionnaire will be distributed to contractors, consultant, architect, developers and engineers for feedback. Mail surveys are among the least expensive. This is the kind of survey the author can do because the author has the names and addresses of the target population, but not their telephone numbers.

   The author chooses this method because mail surveys allow the respondent to answer at their leisure, rather than at the often inconvenient moment they are contacted for a phone or personal interview. For this reason, they are not considered as intrusive as other kinds of interviews.

2. Email Survey

   Email survey was chosen as part of the distribution method, also as a back up survey. Email surveys are both very economical and very fast. More people have email than have full Internet access. This makes email a better choice than a Web page survey for some populations. There is practically no cost involved once the set up has been completed. An email questionnaire might be able to gather several thousand responses within a day or two.

Data Collection, Coding, Editing and Expansion

For data collection, a simple procedure is shown below:

1. Mail a pre-card to sample informing them of forthcoming questionnaire.
2. Mail first packet which include:
    - Cover letter
    - Questionnaire
    - Pre-addressed, stamped return envelope
    - Incentive
    - Return card, mailed flat, commemorative stamps, etc
3. Postcard reminder
4. First follow – up
5. Postcard reminder
6. Phone call reminders
7. Other follow ups if deem appropriate. Up to 6 have proven successful.
8. Control non response error

Data coding and editing is defined as the transferrable of information process from survey forms into computer files. This information is ready for the analysis process. Coding is a process of getting the data from the survey instrument into the computer. Editing information is about cleaning the data and making sure that it is ready for use.

Weighting and expansion of data is a process of having the sample data represent the population from which it was drawn as nearly as possible. Weighting and expansion are two separate processes where weighting is known as an adjusting process that balances within the data to remove biases. While expansion is define as inflating the size of the sample data set to represent the size of the population.

Data analysis

The analysis method that been used in this project is statistical analysis method. Data were analyzed by sorting them in a table (refer chapter 4: Result) and also in bar chart. Result from the survey were analyzed by discussing on the different obtained based on the response received.

There are 4 types of data can be analyzed which are:

1. Nominal

   Distinguishable, cannot be ranked. Eg: gender, religious
2. Ordinal

   Can be ranked, difference cannot be quantified. Eg: strength of agreement.
3. Interval

   Difference can be quantified, not true zero. Eg: temperature
4. Ratio

   Difference can be quantified, with true zero. Eg: weight, length

Data presentation

Data could be present by using few types such as table, summary statistic and graphics. Table could be used when project needed exact numeric values and localized comparison. Summary statistics can be used like below:

Number of points	11
Mean of X	9.0
Mean of Y	7.5
Regression	$y = 3 + 0.5x$
Correlation coefficient (r)	0.82
Level of explanation (r^2)	67%

More than 10 data points are needed in order to present data using the graphic method. Graphic method is used to show big picture and not fine data. There are 2 types of graphic method which are:

1. Graphics for categorical variables

   Bar & Column charts, Pie chart

2. Graphics for continuous variables

   Line graphs, Area charts, Scatter plots, 3D plots

3.3. Research Process Methodologies

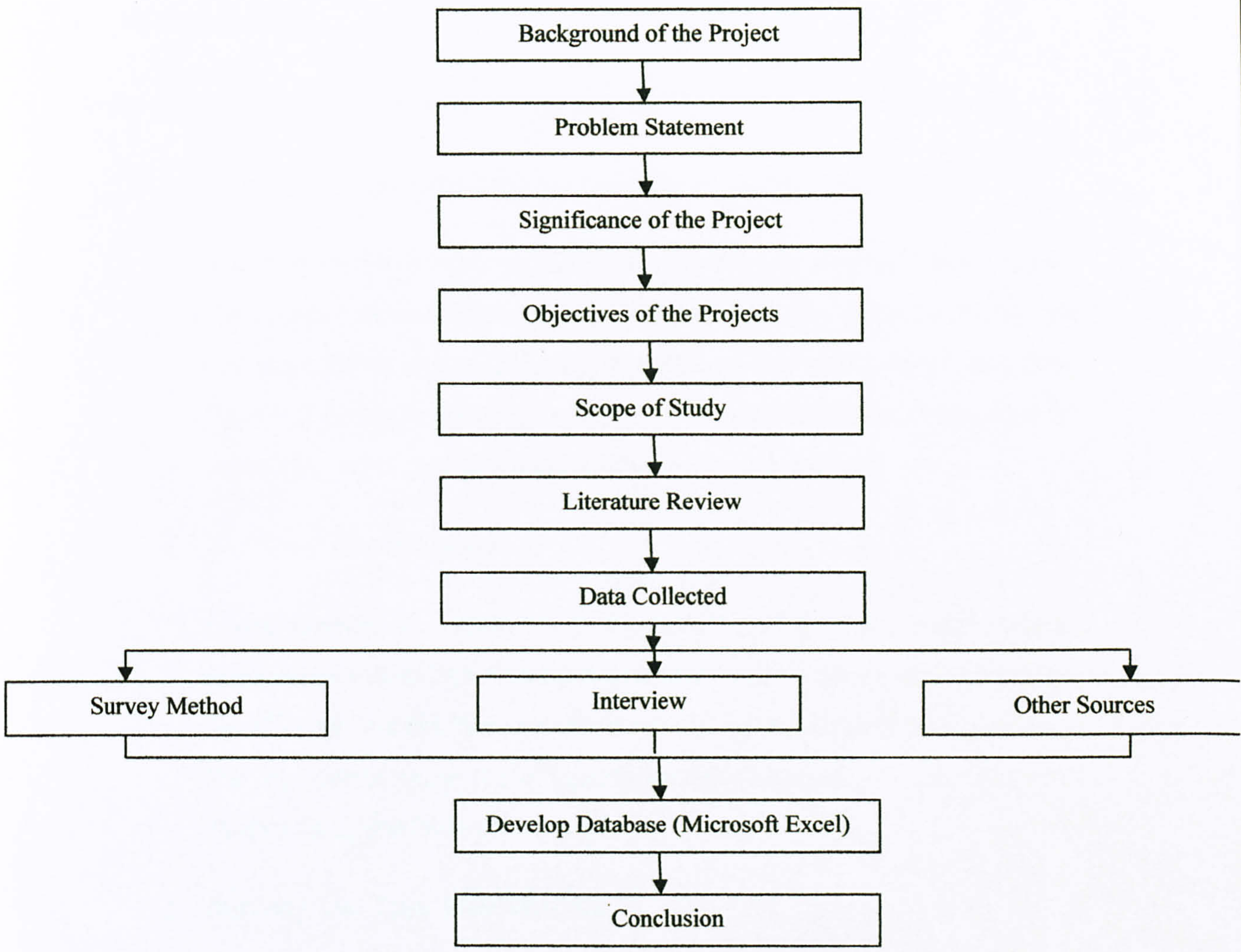


Figure 3.3 Flow Chart for Research process

3.4. Analysis

This research will use statistic analysis to compare and to obtain the final results. Statistical analysis consists of tables, graphics, and mean and variance method.

3.5. Tools Required

There were no specific tools required in this research as this is not an experiment research. This research is mainly on survey method research and the main required tools required are only questionnaire/survey tools.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Survey Process

As for today, there were a few progresses achieved for this research which are:

1. Finalized Questionnaire

   The first task to be completed for the finale year project 2 is to finalize the questionnaire that need to be submitted to the respondents. A few major problems occurred during this process that affect the project flow. To avoid delay in the project flow, a trial submission has been done by submitting 50 copies of questionnaire to one type of company.

2. Distribute Questionnaire

   Questionnaire was distributed via mailing. There were two sets of questionnaire distributed to the respondents which are questionnaire from the 6^{th} draft and the final questionnaire. 50 questionnaires were mailed to the respondent using the 6^{th} questionnaire draft and 300 questionnaires mailed using the final questionnaire.

3. Submit Class Timetable/schedule

   A list of time table was required from each student in order to arrange date for the group meeting and also individual meeting. Schedule was submitted in the week 3 of the campus semester.

4. Receive Questionnaire

   After 2 weeks distributing questionnaires to all respondents mainly in peninsular Malaysia, replied from companies started to receive. Letters / questionnaires were sent back directly to Civil Department where the questionnaires can be obtained at the mail box provided in the civil office.

5. Questionnaire Alteration

   From the responses received, it was shocked to found that there was a huge different in the amount and type of questionnaire received. From the lack of response received, discussion has been made and the questionnaires need to be change for the purpose of other survey method/process.

6. Questionnaire Distribution via Fax, Call Interview and Email.

   Based on opinions and discussions did with the supervisor, an immediate action taken in getting more responses before the analysis process started. Survey planned to be done by submitting the questionnaire using fax machine, email directly to the company and also by call interview.

7. Questionnaire received from fax, call interview and email

   About 15 companies involved in the process of distributing questionnaire via fax, call interview and email. Among these three methods, respondents mostly preferred to fax the questionnaire to them than other mailing method. There are only two respondents that willing to answer the questionnaire by call interview. But both of them also required for faxing the questionnaire to them. From 15 respondents, there were only 5 respondents that response to the survey.

4.2. Analysis Process and Result

The survey process started by submitting the final questionnaire on precast production rate to companies selected during the sampling process. From the graph shown in figure 4.1, there were 350 selected companies chosen to answer the questionnaire. Unfortunately, there were only 20 companies that response to the survey perfectly. 6 % of companies reply to the survey and it is quite a huge range between the total amount of companies received the questionnaire. This low percentage of respondents has been expected when conducting a survey based on mail and fax.

This problem is normally happen to those who conducting a survey in the construction industry. The reasons are the company staffs especially the manager did not have enough time and too busy with their works. Lack of corporation and awareness about the important of this survey for our industry make them neglected and ignored the questionnaire.

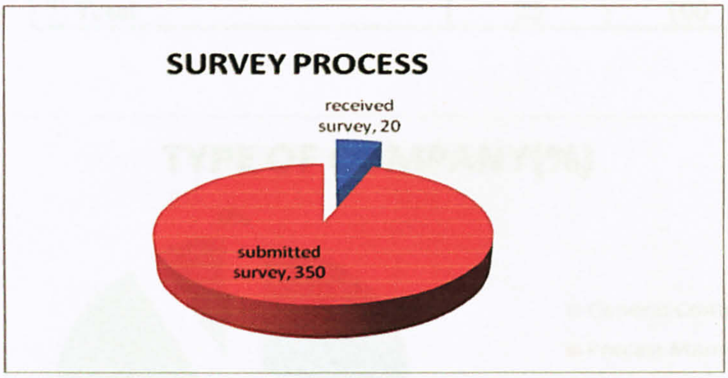


Figure 4.1 Percentage of companies that response to survey

It is obvious that the major respondents that response to the survey was from Precast Manufacturer Company. Based on the figure 4.2, 40% or 10 of total company response to the survey were from precast manufacturer. General contractor is the second highest company response to the survey with the amount of 7 replied or at 28% out of total 100% response. 6 companies from Precast Contractor involved in the survey with the percentage of 24% while 8% of companies from Precast Consultant which are 2 companies that contributed in this survey process.

Even though at first, only 50 questionnaires submitted to the Precast Manufacturer company, but from the response received, it shows that this company was really corporate and interested in this survey of precast production rate. Compare to the total amount of 300 general companies that received the survey, only 10 companies that replied to the survey perfectly.

Table 4.1 : Types of company participate

Type	Numbers	%
General Contractor	7	28
Precast Manufacturer	10	40
Precast Contractor	6	24
Precast Consultant	2	8
Other	0	0
∑ Total	25	100

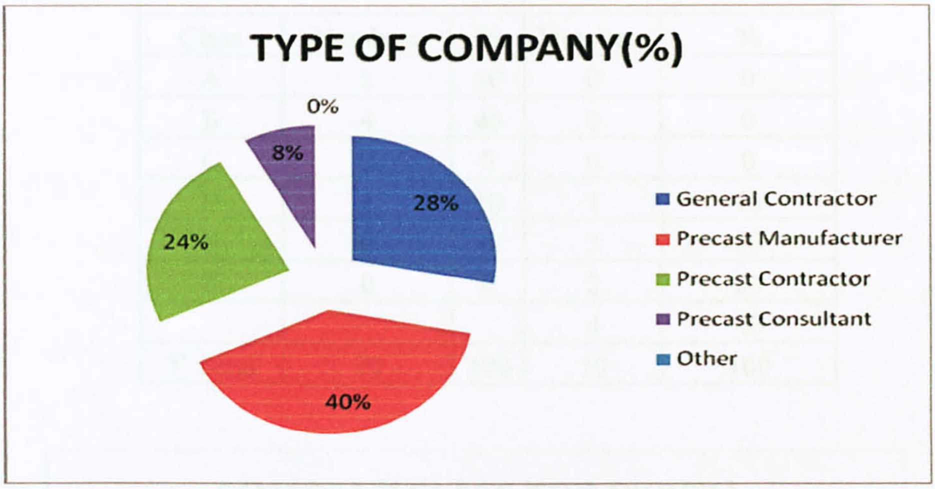


Figure 4.2 Percentage of Respondents according to Type of Company

Like what have author expected, the majority class of company that response to the survey are from Class A and B for companies under PKK and also from G7, G6 and G5 companies under CIDB. The range different of response between each main groups are not that high where as shown to Figure 4.3, at the range of 40% to 50% responses are from companies Class A and Class B.10% of companies from class D also involved in this survey. This shows their effort to at least contribute a little information and knowledge to help developing the precast production rates. For company with class G7, G6 and G5, all of them scored with 40% (4 companies), 20% (2 companies) and 30 %(3 companies) out of the total 100% response from CIDB companies (Figure 4.4). 10% of companies from G4 response to the survey and it seem that companies that under CIDB were more familiar with precast construction than companies from PKK groups.

Companies from class A, B and from G7, G6 and G5 might be more interested in this survey as they have more experienced and knowledge involving construction of precast system compare to small companies. It is because, most of precast systems were used for high rise project and for small companies, they would rarely involve in a high rise project and this makes them have little knowledge in precast construction system.

Table 4.2 : Company Class

PKK			CIDB	
Class	Numbers	%	Numbers	%
A	5	50	0	0
B	4	40	0	0
C	0	0	0	0
D	1	10	1	10
E	0	0	3	30
F	0	0	2	20
			4	40
∑ Total	10	100	10	100

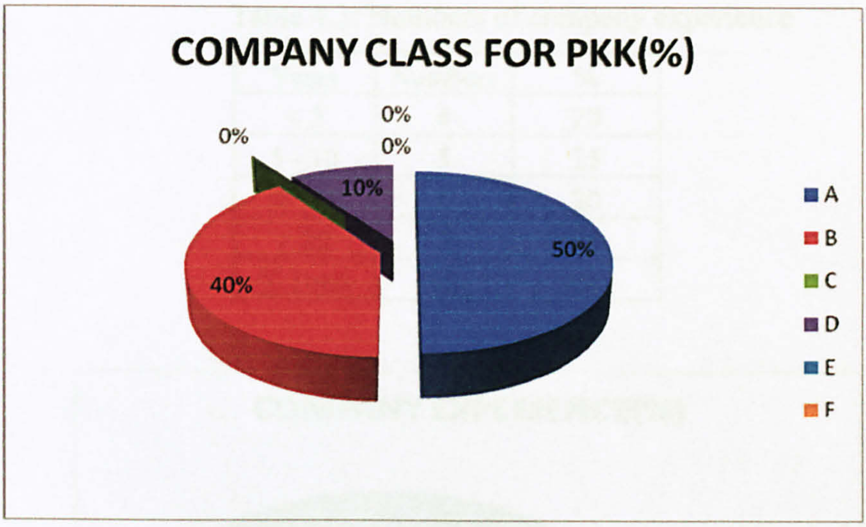


Figure 4.3 Percentage of respondents according to class of contractor.

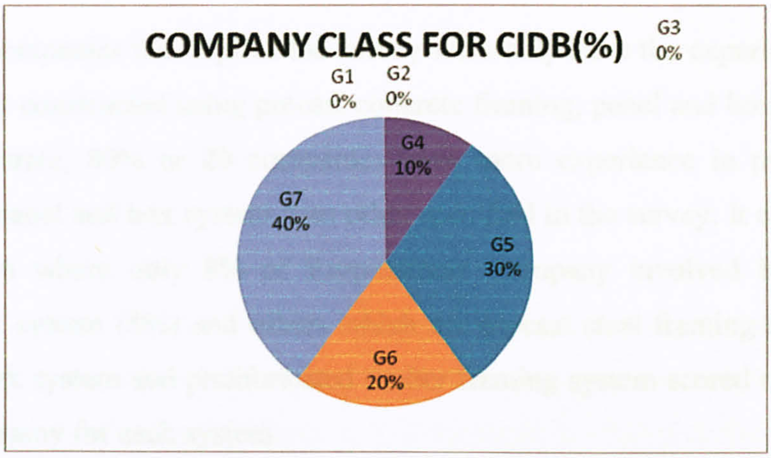


Figure 4.4 Percentage of Respondents according to CIDB

From Figure 4.5, 20% of companies have an experienced in precast system for 10 to 20 years. This is similar to companies that had gained experienced in precast system for less than 5 years. A 5-10 years of experienced companies involved in this survey which have the percentage of 25% while the most experienced companies response to this survey were from companies that have more than 20 years experienced which is 35% out of the total 100% percentage.

Table 4.3: Numbers of company experience

Years	Numbers	%
< 5	4	20
5 - 10	5	25
10 - 20	4	20
> 20	7	35
∑ Total	20	100

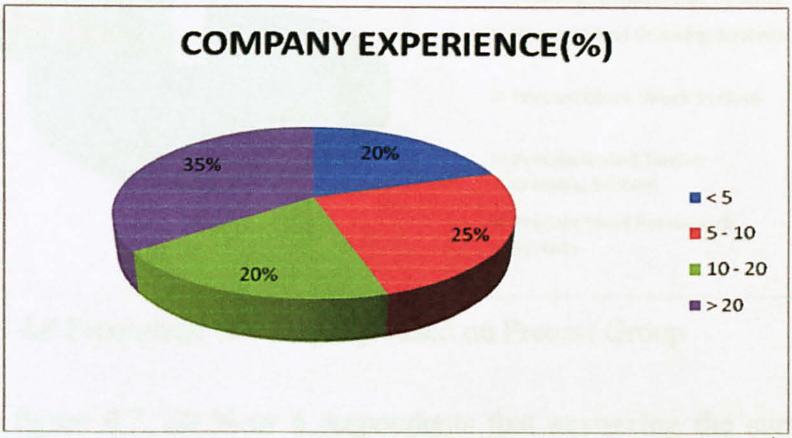


Figure 4.5 Percentage of Company Experienced

Most of companies that replied the survey were only have the experienced involved in projects constructed using precast concrete framing, panel and box system. To be more accurate, 80% or 20 companies have more experience in precast concrete framing, panel and box system than other specified in the survey. It could be seen in Figure 4.6 where only 8% of Respondents Company involved in precast steel formwork system (8%) and others which are precast steel framing system, precast block work system and prefabricated timber framing system scored only 4 % which are 1 company for each system.

From this result, this survey have to focus or analyze the production rate for precast concrete framing, panel and box system only as there were not enough results/data from other precast group or precast system.

Table 4.4: Numbers of Precast Groups that participate

Precast Groups	Numbers	%
Precast Concrete Framing, Panel & Box System	20	80
Precast Steel Framing System	1	4
Precast Block Work System	1	4
Prefabricated Timber Framing System	1	4
Precast Steel Formwork System	2	8
∑ Total	25	100

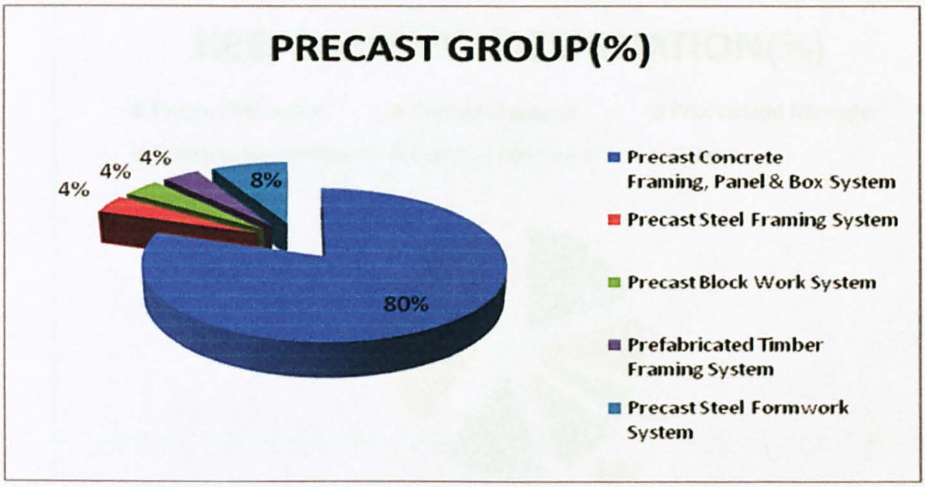


Figure 4.6 Percentage of Company based on Precast Group

As shown in figure 4.7, 20 % or 4 respondents that answering the survey is the Project Manager. While 5% or 3 General Managers had fill up the questionnaire.

Only 10% Project Engineer and Construction Manager involved in this survey and 5% of Production Manager replied this questionnaire. 40% or 8 respondents are from other group which consists of site supervisor, quantity surveyor, financial controller and technical head.

From this result, it could be said that there were lots of construction people that involved in precast system. They come from various or different construction background based on their designation. They might be based at the site or also can be working fulltime at their headquarters/ office. Their different designation will affect this survey result because they have their own overview/opinion about precast system in our industry.

Table 4.5: Respondents' Designation

Designation	Numbers	%
Project Manager	4	20
Project Engineer	2	10
Production Manager	1	5
Construction Manager	2	10
General Manager	3	15
Other	8	40
∑ Total	20	100

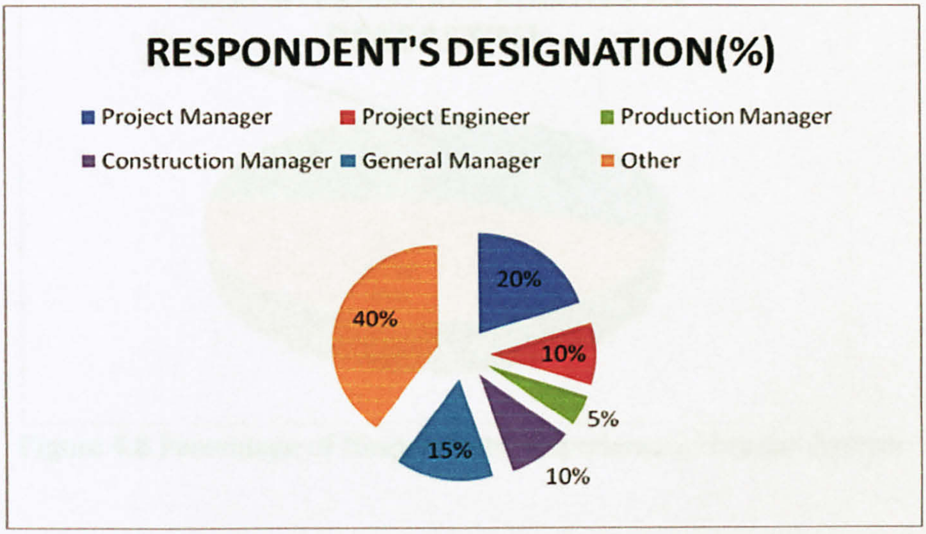


Figure 4.7 Percentage of Respondent's Designation

Based on Figure 4.8, most of respondents have 5-10 years experienced in precast construction. There were about 45% of them had gained experienced in precast system for 5 – 10 years which could be conclude that they are still new in the precast field. 30% or 6 respondents involves in precast field less than 5 years while 20% of them involved in precast system for 10 – 15 years. Even though the most adequate experienced needed to obtain an excellent survey result was more than 15 years experiences, but only 5% or 1 respondents that are qualified enough to be in this group.

It has been expected that most of respondents learned about precast production rate by their own experienced gained through their involvement in project constructions. Figure 4.9 shows that 50% of respondents agreed on gaining sources from experience compare to only 27% from previous related job.

Table 4.6 : Respondents experience in precast

Years	Numbers	%
< 5	6	30
5 - 10	9	45
10 - 15	4	20
> 15	1	5
∑ Total	20	100

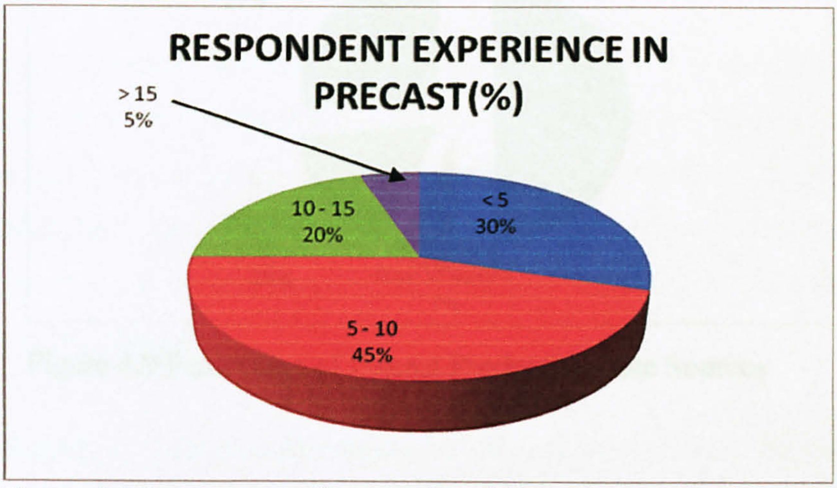


Figure 4.8 Percentage of Respondents' Experience in Precast System

But, both experiences and previous related project are related as they gained their experiences during their works on their previous related projects. 16% of respondents said that they normally estimate the precast production rate using their feeling and instinct and this is also related to their experiences in project construction. Only 7% of respondents replied to this survey using the production rate standard. It shows that our construction industry is still not familiar to the production rate standard and this still standard might have to be update/upgrade as a user friendly system. As this standard become easier to be use or to refer to, people with low knowledge / less experience in the precast production rate system could learn more on the system and could use the standard wisely.

Table 4.7: Sources of Production Rate Value

Sources	Numbers	%
Experience	15	50
Production Rate Standard	2	7
Feeling & Instinct	5	17
previous Related Project	8	27
Literature	0	0
Other	0	0
∑ Total	30	100

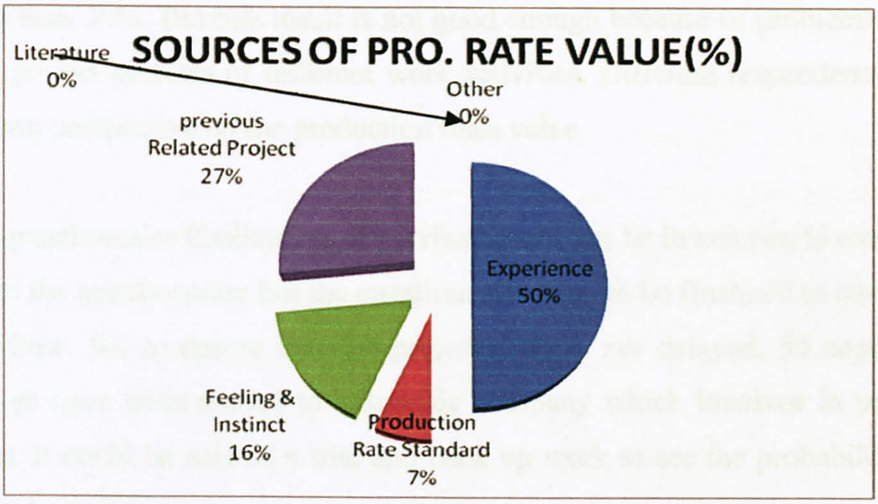


Figure 4.9 Percentage of Precast Production Rate Sources

Table 4.8: Precast Production Rate (unit/day)

ACTIVITIES	RESPONDENTS																				VARIANS	MEAN
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
a) Setting Out	22	26	-	20	30	14	20	22	15	20	30	25	15	15	21	20	20	25	30	25	27	22
b) Wall Positioning	15	28	18	21	21	14	20	15	20	18	16	19	20	20	15	19	20	22	25	18	11	19
c) Wall Adjustment	25	20	18	20	21	15	20	15	18	14	19	20	15	20	18	15	20	20	22	18	6	18
d) Beam Setting Out	28	30	18	25	16	11	30	20	25	18	25	18	15	17	20	22	26	30	22	20	29	21
e) Floor Setting Out	30	33	36	28	25	14	40	20	24	30	25	28	25	25	20	28	26	30	30	25	34	27
f) Pour Concrete In-situ Topping	30	25	36	30	25	15	40	25	30	30	33	26	28	30	22	33	35	26	35	31	33	29
g) Staircase	15	19	18	15	12	15	10	13	15	17	18	14	15	19	10	13	17	12	12	18	8	15

For the precast concrete framing, panel and box system production rate result, the average different between variance and mean of the production rates varies around 5—10 (Table 4.8)). For an example, the wall positioning activities, the mean of total production rates is 19 unit/day while the variance is 11 unit/day. The different between both results are 8. It could be said that the precast production rates for concrete framing, panel and box system is reliable as the different of variance and mean is less than 50%. But this result is not good enough because of problems such as different project consists of different work activities. Different respondents also have their own perspective on the production rates value.

During the questionnaire finalization, supervisor could not be in campus to evaluate and finalized the questionnaire but the questionnaire need to be finalized to continue the project flow. So, to ensure that the project process not delayed, 50 copies of questionnaires have been mailed to a specific company which involves in precast manufacture. It could be said as a trial and back up work to see the probability for the survey to be response.

When he started his worked, a discussion has been made and the questionnaire were evaluated and changed. It is because the 6th questionnaire was being told too simple and unsatisfied the standard. The questionnaire was changed to a more standard and specific questionnaire based on the discussion made during the first meeting.

300 copies of questionnaires that been finalized has been distributed to all types of construction companies around Malaysia. Three weeks is given to the companies to

reply to the survey. The questionnaires can be replied by mailing back the letter to the university with the attention to the people involves. The companies also were provided an envelope and stamp to make the mailing work easier and smooth.

After complete the first half of the project's planned, a short meeting has been made between people involved in this FYP 2. The main purpose of this meeting is to submit a copy of timetable/schedule for one week of classes. It is to set and arrange a suitable time to have an individual meeting between the supervisor and the student. It is easier to meet and discuss individually compare to a group of people discussing all the problems arise between them. The supervisor could pay a full attention to the individual and helping solving problems.

When the second half of semester started, responses from companies started to receive. Survey receive could be collected at the Civil Department's office where the survey obtained at the provided mail box. Surveys were collected every two days to ensure that the survey did not mess up or loss. The amount and progress of surveys received was kept updated with the supervisor in order to keep the project flow/planned on going.

Unfortunately, for this project, there was a major problem where survey received from respondents was not that impressive. Respondents tend to ignore the main section of the survey that really needs their full attention which is section B : Production Rates of Precast. In this section, respondents are supposedly to give the value of every precast system production rate in unit/day.

The amount of surveys answered completely and not complete can be said equally the same. Most of surveys that been answered completely were replied from precast manufacturer where as the surveys that did not complete were from contractors and consultant. It is a major problem because the questionnaires submitted to precast manufacturer were only 55 copies but for contractor and consultant were 300 copies.

The 55 copies of questionnaires submitted to precast manufacturer were from the trial and back up work did at the early semester. The 300 copies of questionnaires sent to contractors and construction companies were the finale questionnaire.

From a few of respondent opinions, they said that the questionnaire given was complicated to be answered and it takes time for them to response to his survey. From the result obtained also it could be said that the respondents preferred a simple questionnaire (6th questionnaire) compare to the finale questionnaire. There were respondents that did not have any experiences in precast construction and it makes the survey process become harder and if there are respondents that have lots of experiences in precast construction, they did not answered the questionnaire completely.

Among all the response obtained from the questionnaire, majority of the respondents did not answer or fill in the precast production rate part. Some of the respondents did not have the precast background but yet still answer the questionnaire.

Their different understanding in the precast production rate part also gave difficulty to the survey being analyzed. Some of the respondents gave answered based on floor size and few of them gave answered in bulk or general.

These situations make it difficult to continue with the analysis process as the results received were insufficient enough (less than 10 completed responses). An urgent meeting was held on Thursday 13th March 2008, discussing about the problems occurred. Analysis and comparison made between both types of questionnaires submitted earlier.

The latest action and planned was altered the questionnaire by combining last two questionnaire and become one simple and perfect questionnaire. Different alternatives taken in order to increase the amount of answered questionnaires such as faxing, emailing the latest questionnaire to several manufacturers and class A contractors and also by phone interviewing respondents. At least 20 questionnaires are hoping going to receive before the analysis process started.

In future, few correction or prevention needs to be done in order to improve the questionnaire response. Firstly, the questionnaire should probably send directly to the person that involves with site work or precast works. Respondents from different background of works should not answer the survey because they might answer the questionnaire incorrectly.

The questionnaire design should also been improve such as the precast production rate part might be in multiple choice. It may give interest to the respondents to answer the questionnaire as they does not have to spent much time to think and consider the amount of precast production rate.

From the analysis made, it shows that respondents prefer more simple and easy to be answer kind of questionnaire. They required a short time to response on the survey and it is very important to make the questionnaire as simple as it possible. The types of companies choose should be monitored and wisely selected to ensure that respondents are qualified enough to answer the survey.

Respondents should been selected based on their companies specialization and respondent's expertise. Lots of respondents did not have any knowledge in precast system mainly from class C contractor and few from class B contractors. The survey should have concentrated more to precast manufacturer than contractor. It was based on the responses received where the major responses were from precast manufacturer.

From the above discussion, it can be concluded that the results may not be immediately used for construction purposes. However it could be accepted as an indication to the characteristics of precast production rates in Malaysia and used for development of more reliable database in the future.

4.3. Findings

a. Some of the contractors in Malaysia prefer to use past project duration records which are then re-estimated, rather than detail production rates for planning and scheduling works.

b. Most contractors in Malaysia are familiar with speed of structural construction in terms of summation of duration which a storey of building could be build, rather than figures of production rates for each precast construction trades.
c. Some of the PKK Class A contractor (main contractor) relies on their sub-contractor experience in estimating production rates as it is their sub-contractor which will do the precast construction works, whereas the main-contractor usually manage the project from a higher level.
d. In Malaysian construction project, it is common to have many revisions of project schedule, thus the accuracy of the first project schedule is not highly emphasize as eventually the schedule will need to be changed

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

IBS features potential construction system for the future with emphasis on quality, higher Productivity and less labor intensive. Besides the aim of gradually reducing the dependency on foreign labor and saving the country's loss in foreign exchange, IBS provides the opportunity for the players in the construction industry to project a new image of the industry to be at par with other manufacturing-based industry such as the car and electronic industries.

The adoption of IBS promises to elevate every level of the construction industry to new height and image of professionalism. IBS should be seen as the modern methods of construction where modern and systematic methods of design, production planning and mechanized methods of manufacturing and erection are applied. The production rates of precast construction could minimize the cost, time, labor and lots more need in a construction.

The sequence of activities in IBS system at site especially Precast Concrete Framing, Panel and Box Work System had been identified through out this project. The objective of this project which is to collect, complies and analyzes the precast production rates' values from the industry also has been achieved. The analysis has been done using the statistical analysis method that consists of table, pie chart, mean and variance of the data obtained from the survey conducted.

This project was also has been a starting point in developing the precast production rate database based. Lots of factor should been considered in conducting this survey. And one of the factors is the companies involved should have been chosen and analyze before questionnaire submitted to them.

A simple but full of information questionnaire should been design in other to make the survey process flow smoothly. Cost of the project should be increase more than RM250 as it's really help in improving the survey result. Survey could be sent more than 350 companies and it is easier to make interviews when there are budgets for this activities.

To get the perfect or accurate results of precast production rates, survey should been done on site, meaning that the person who conducting the survey should have did the survey at site. The time constraint and the cost of doing the survey by interviewing respondents at their site or project affect this study.

This project is hoping to be continued by the next future civil engineering students in order to develop a perfect/full database for precast production rates'. Factors that affect this study should be taken seriously while doing the survey in the future undertaken in order to achieved a better result.

CHAPTER 6

REFERENCES

AbouRizk S., Knowles P. and Hermann U.R. 2001 "Estimating Labor Production Rates for Industrial Construction Activities" *Journal of Construction Engineering and Management*, Volume 127, Issue 6, pp. 502-511 (November/December 2001)

Ahamd Baharuddin 2006 " Issues and Challenges in the Implementation of IBS in Malaysia" *Proceeding of the 6th Asia Pacific Structural Engineering and Construction Conference.*

A. Samer Ezeldin and Lok,am M. Sharara (2006) "Neural Networks for Estimating The Productivity of Concreting Activities" *Journal of Construction Engineering and Management ASCE* pp. 650-656.

Baker K.R.1974, *Introduction to Sequencing and Scheduling*, New York John-Wiley and Sons.

HITEC, July 2001, Evaluation of the Con/Span Wingwall System

Hendrickson, C., D. Martinelli, and Rehak D. 1987, "Hierarchical Rule-based Activity Duration Estimation," *ASCE Journal of Construction Engineering and Management*, Vol 113, No. 2, 1987, pp. 288-301

Hendrickson C. 1989, *Fundamental Concepts for Owners, Engineers, Architects and Builders*, Prentice Hall.

James T. O'Connor M.ASCE and Youngki Huh (2006) "Crew Production Rates for Contract Time Estimation : Beam Erection, Deck and Rail of Highway Bridges" *Journal of Construction Engineering and Management ASCE* pp. 408-415.

John Christian and Daniel Hachey "Effects of Delay Times on Production Rates in Construction" *Journal Of Construction Engineering and Management* pp. 20-26.

Kim S. Elliott, 2002, Precast Concrete Structures, Butterworth Heinemann

Proverbs D.G., Holt G.D. and Olomolaiye P.O. 1997 "European Construction Contractors: a Productivity Appraisal of in-situ Concrete Operatins" *Journal of Construction Management and Economics*, Vol 17, 1997, pp. 221-230.

Proverbs D.G., Holt G.D. and Olomolaiye P.O. 1997 "A Comparative Evaluatio of Concrete Placing Productivity Rates amongst French, German and UK Construction Contractors" *Journal of Engineering, and Architectural Management*, Vol 5, No. 2, 1998, pp. 221-230.

Richard Fellows & Anita Lui. Research Methods For Construction, Blackwell Publishing 2002

Robert E. Englekirk, 2003, Seismic Design of Reinforced And Precast Concrete Buildings, John Wiley & Sons, INC

The Business Roundtable, *More Construction for the Money*, Summary Report of the Construction Industry Cost Effectiveness Project, January 1983, p. 11

Thomas H.R., Matthews C.T. and Ward J.G. 1986, "Learning Curve Models of Construction Productivity," *ASCE Journal of Construction Engineering and Management*, Vol. 112, No. 2, June 1986, pp. 245-258.

APPENDICES

UNIVERSITI TEKNOLOGI PETRONAS

18th March 2008

Dear Sir/Madam,

The Development of a Database for Precast Works' Production Rate

We seek your help in a university research survey on the implementation of development of a database for precast works production rate within construction industry in Malaysia especially around peninsular of Malaysia.

In Malaysia, there is no formal database for the production rates of precast construction implemented compared to the total amount of companies in this industry. The production rate systems now are mainly focusing on construction industry and there were no database that focusing mainly in precast construction works. By doing this research, we are hoping that it will be a starting point in implemented a database for precast works' production rate.

Precast production rates could be defined as the amount of precast works that could be done a certain period of time. By implementing precast production rate's database system, it might help our industry in calculating all the resources needed in precast works and at the same time will help promoting the use of precast to the government and the industry as well.

We have devised a questionnaire which we would like you to complete and return and which will only take no more than 15 minutes of your time. With your cooperation, we should be able to collect as many data as possible regarding the development of a database for precast works' production rate.

It would help us very much if you could complete and return the questionnaire before 20thMarch 2008. As an enclosure to this letter, please find a self-addresses and stamped envelope to return the questionnaire. You can also fax to us at 05-3656716 , attention to Dr Arazi/Zairul Aziya.

Please contact Ms. Zairul A'ziya bt Zulkefli (012-6830988) if you have any questions regarding the survey.

Yours sincerely,

____

(Assoc. Prof. Ir. Dr. Hj. Muhd Fadhil Nuruddin)
Head Of Civil Engineering Department,
Universiti Teknologi PETRONAS

Cc: Assoc. Prof . Ir. Dr. Arazi Idrus
Ms Zairul A'ziya Bt Zulkefli

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out. The objective of this final year project is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 3 sections which are A, B and C. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [ ] provided.

I. Company:

1. Name of Company: ______________________

2. Type of Company: [ ] General Contractor [ ] Precast Contractor [ ] Precast Manufacture

3. Class (if applicable, for contractor):

a. PKK A[ ] B[ ] B[ ] C[ ] D[ ] E[ ] F[ ]

b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)

<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

II. Respondents' Information

1. What is your designation with the company?

[ ] Project Manager [ ] Construction Manager

[ ] Project Engineer [ ] General Manager

[ ] Other: ____

2. Respondent's experience in Precast Works? _______ Years

Section B : Precast Works

Please fill in the blank.

1. How many projects have your company completed? ________________
2. How many projects were completed using Precast? ________________
3. Percentage of Precast usage in completed project? _______%
4. How much knowledge you possessed about Precast Works? Please tick.

   [ ] None [ ] Average [ ] Excellent

5. Which Precast component/s are you using?

   [ ] Precast Concrete [ ] Steel Formwork [ ] Steel Frames
   [ ] Timber Frames [ ] Block Work
   [ ] Other: ________________

6. What are the advantages of Precast Work compared to conventional system?

   [ ] Cleaner, neater and safe construction site
   [ ] Open / flexible system
   [ ] Enhancing quality of finished products
   [ ] Lowering total construction cost
   [ ] Easy installation
   [ ] Labour reduction
   [ ] Fast completion

7. What are the sequences of activities in Precast system at site (sample building)

   ____
   ____
   ____
   ____
   ____
   ____

8. How much knowledge you possessed about precast?

   [ ] Excellent [ ] Average [ ] None

Section C : Production rates

Please fill in the blanks

1. How many Precast Concrete Framing, panel & box system) do you used in 1 day for:

(a) Beam : ________________

(b) Wall : ________________

(c) Slab : ________________

2. How many Precast Panel & Box System do you used in 1 day for:

(a) Beam : ________________

(b) Wall : ________________

(c) Slab : ________________

3. How many Block Work Systems do you used in 1 day for :

(a) Concrete Masonry Unit (CMU) : ________________

(b) Light Weight Block : ________________

4. Where do you get the planned and actual (if any) production rates' values in scheduling works?

____

____

5. What is the methodology applied in measuring the planned and actual (if any) production rates?

____

____

6. Do you have any production rates database that is used in the company's scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research?

[ ] Yes, and it can be shared

[ ] Yes, and it can't be shared

[ ] No

7. Please feel free to write any comment related to the topic of the study.

____

____

____

____

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by **11th January 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idruz).**

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are Pre-cast Concrete Framing, Panel and Box System and Block Work System. The objective of this final year project is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 3 sections which are A, B and C. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [ ] provided.

I. Company:

1. Name of Company: ____________________________

2. Type of Company: [ ] General Contractor [ ] Precast Contractor [ ] Precast Manufacture

3. Class (if applicable, for contractor):

a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]

b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)

<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

II. Respondents' Information

1. What is your designation with the company?

[ ] Project Manager [ ] Construction Manager
[ ] Project Engineer [ ] General Manager
[ ] Production Manager [ ] Other: ____________________

2. Respondent's experience in Precast Works? ________ Years

III. Precast Experience

1. Which Precast component/s are you using?

[ ] Precast Concrete [ ] Steel Formwork [ ] Steel Frames
[ ] Timber Frames [ ] Block Work
[ ] Other: ________________

2. What are the advantages of Production Rates in Precast Work compared to Conventional System?

[ ] Fast completion
[ ] Lowering total construction cost
[ ] Easy installation
[ ] Labor reduction
[ ] Other: ________________

Section B: Production Rates of Building Progress

Please use your own unit to answer question 1, 2 and 3.

For example: Precast Manufacturing: m^3/hr
Precast Installation (Contractor): unit/hr

I. Production Rate Information

1. How many Precast Concrete Framing do you installed in 1 day (8hours) for:

(a) Beam : ________________

(b) Column : ________________

(c) Beam & Column : ________________

2. How many Precast Panel & Box System do you installed in 1 day (8hours) for:

(a) Wall : ________________

(b) Slab : ________________

3. How many Block Work Systems do you installed in 1 day (8hours) for?

(a) Concrete Masonry Unit (CMU) : ________________

(b) Light Weight Block : ________________

4. Where do you get production rates' values for your project planning & scheduling works?

[ ] Experience [ ] Previous Related Project

[ ] Production Rate Standard [ ] Literature

[ ] Feeling & Instinct [ ] Other: ________________

5. What is the methodology applied in measuring production rates?

____

____

II. Other Related Information

1. Do you have any production rates database for Precast Construction that is used in your project planning & scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research?

[ ] Yes, and it can be shared

[ ] Yes, and it can't be shared

[ ] No

7. Please feel free to write any comment related to the topic of the study.

____

____

____

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by **11th January 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idruz).**

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done at a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are Pre-cast Concrete Framing, Panel and Box System, Precast Steel Framing System and Precast Block Work System. The objective of this research is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 2 sections which are A and B. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [ ] provided.

I. Company:

1. Name of Company: ____________________________

2. Type of Company: [ ] General Contractor [ ] Precast Contractor
[ ] Precast Manufacture [ ] Precast Consultant
[ ] Other: ______________(please specified)

3. Class (if applicable, for contractor):

a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]
b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)
<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

5. Which Precast component/s are you using?
[ ] Precast Concrete [ ] Steel Formwork [ ] Steel Frames
[ ] Timber Frames [ ] Block Work
[ ] Other: ________________

II. Respondents' Information

1. What is your designation with the company?
[ ] Project Manager [ ] Construction Manager
[ ] Project Engineer [ ] General Manager
[ ] Production Manager [ ] Other: ____________________

2. Respondent's experience in Precast Works? _______ Years

Section B: Production Rates of Building Progress

I. Production Rate Information

1. Please fill in the production rates in the table below using your own preferred unit. For examples : m^3/hr, units/hr, m^3/day

Activities	Concrete Framing, Panel & Box Systems	Steel Framing Systems	Block Work Systems
Erect column include supporting false work			
Lift and place beams			
Join beams			
Lift prefab floor units			
Erect false work for floor			
Position prefab floor units			
Seal joints between floor units			
Install continuity bars			
Install topping bar (mesh)			
Install edge formwork			
Pour in-situ topping			
Curing concrete topping			

II. Additional Information

1. Overall numbers of precast production rates

   a) Numbers of days to complete a floor slab for building: ___________

   b) Numbers of days to complete one (1) storey of building in bulk: _________

2. Where do you get the precast production rates' values for your project planning & scheduling works?

[ ] Experience
[ ] Production Rate Standard
[ ] Feeling & Instinct
[ ] Previous Related Project
[ ] Literature
[ ] Other: ________________

3. What is the methodology applied in measuring precast production rates?

____

____

III. Other Related Information

1. Do you have any production rates database for Precast Construction that is used in your project planning & scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research?

[ ] Yes, and it can be shared
[ ] Yes, and it can't be shared
[ ] No

7. Please feel free to write any comment related to the topic of the study.

____

____

____

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by **11th January 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idruz).**

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done at a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are Pre-cast Concrete Framing, Panel and Box System, Precast Steel Framing System and Precast Block Work System. The objective of this research is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 2 sections which are A and B. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [ ] provided.

I. Company:

1. Name of Company: ____________________________

2. Type of Company: [ ] General Contractor [ ] Precast Contractor
[ ] Precast Manufacture [ ] Precast Consultant
[ ] Other: ______________(please specified)

3. Class (if applicable, for contractor):
a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]
b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)
<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

5. Which Precast component/s are you using?
[ ] Precast Concrete [ ] Steel Formwork [ ] Steel Frames
[ ] Timber Frames [ ] Block Work
[ ] Other: _______________

II. Respondents' Information

1. What is your designation with the company?
[ ] Project Manager [ ] Construction Manager
[ ] Project Engineer [ ] General Manager
[ ] Production Manager [ ] Other: ___________________

2. Respondent's experience in Precast Works? _______ Years

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done at a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are Pre-cast Concrete Framing, Panel and Box System, Precast Steel Framing System and Precast Block Work System. The objective of this research is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 2 sections which are A and B. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [ ] provided.

I. Company:

1. Name of Company: ____________________________

2. Type of Company:
   [ ] General Contractor [ ] Precast Contractor
   [ ] Precast Manufacture [ ] Precast Consultant
   [ ] Other: ______________ (please specified)

3. Class (if applicable, for contractor):
   a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]
   b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)
   <5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

5. Which Precast component/s are you using?
   [ ] Precast Concrete [ ] Steel Formwork [ ] Steel Frames
   [ ] Timber Frames [ ] Block Work
   [ ] Other: ______________

II. Respondents' Information

1. What is your designation with the company?
   [ ] Project Manager [ ] Construction Manager
   [ ] Project Engineer [ ] General Manager
   [ ] Production Manager [ ] Other: ____________________

2. Respondent's experience in Precast Works? ________ Years

Section B: Production Rates of Building Progress

I. Production Rate Information

1. Please fill in the production rates in the table below.

Activities	Concrete Framing, Panel & Box Systems (unit/day)	Steel Framing Systems (unit/day)	Block Work Systems (unit/day)
Setting Out			
Wall Positioning			
Wall Adjustment			
Beam Setting Out			
Slab Setting Out			
Staircase			

II. Additional Information

1. Overall numbers of precast production rates
   a) Numbers of days to complete a floor slab for building: ___________
   b) Numbers of days to complete one (1) storey of building in bulk: __________

2. Where do you get the precast production rates' values for your project planning & scheduling works?

[ ] Experience
[ ] Production Rate Standard
[ ] Feeling & Instinct
[ ] Previous Related Project
[ ] Literature
[ ] Other: ___________________

3. What is the methodology applied in measuring precast production rates?

____

____

III. Other Related Information

1. Do you have any production rates database for Precast Construction that is used in your project planning & scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research?

[ ] Yes, and it can be shared [ ] Yes, and it can't be shared [ ] No

7. Please feel free to write any comment related to the topic of the study.

____

____

____

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by **29th Febuary 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idruz).**

The Procedure

• Setting Out
1. Surveyor to set cross reference.
2. Transfer grid and mark wall position on slab.
3. Mark 100mm offset line from rear building edge.
4. Offset wall position by 200 mm.
5. Secure 2x2 timber to the floor at wall edge to guide wall.

• Wall Positioning
1. The first wall in place has to be the partition wall at the rear.
2. Mark a line parallel to and 100mm from the external edge of the wall.
3. Place shim plate @500 c/c on the floor and level to wall soffit. Shim plate may also be placed on Non-shrink mortar bed and allow to set.
4. Adjust position of the dowel bar.

• Wall Adjustment
1. Position adjacent walls and plumb wall corners at 200 mm offset
2. Adjust verticality until within +2 or –2 mm
3. Ensure the four faces of every walls are adjusted
4. Position string 250 mm from face of walls
5. Walls within the same line are to be adjusted within same tolerance
6. Ensure air-pocket is fully grouted.

• Beam Setting Out
1. Cast wall joint.
2. Mark 1 m reference line.
3. Confirm pocket level. Position shim plate to correct beam soffit level if required.
4. Mark position of beam on floor.
5. Hoist beam in place and check top level.
6. Plumb beam to verify position on floor below.
7. Ensure beam verticality with a spirit level.
8. Wedge beam against pocket and grout the gap between the beam and the wall.

• Slab Setting Out I
1. Position the slab temporary supports and adjust the slab soffit level approximately.
2. Raise the height of the supports about 5 mm above slab soffit level.

• Slab Setting Out II
1. Hoist slab in place on top of beam and support.
2. Verify level of every plank soffit at four corners and center.
3. Adjust level of temporary support accordingly.

• Staircase
1. Position landing or slab and verify soffit level at four corners.
2. Adjust level to within tolerance.
3. Position shim plates at staircase support location to correct level.
4. Verify level difference between pegs on top and below.
5. Hoist staircase in place.
6. 10mm gap between precast plank and staircase

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done at a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are 1)Pre-cast Concrete Framing 2) Precast Panel System 3) Precast Box System. The objective of this research is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 2 sections which are A and B. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [√] provided.

I. Company:

1. Name of Company: ______________________________

2. Type of Company:
[ ] General Contractor
[ ] Precast Contractor
[ ] Precast Manufacture
[ ] Precast Consultant
[ ] Other: ______________(please specified)

3. Class (if applicable, for contractor):
a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]
b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)
<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

5. Which Precast groups are you using?
[ ] Precast Concrete Framing, Panel & Box System
[ ] Precast Steel Framing System
[ ] Precast Block Work System
[ ] Prefabricated Timber Framing System
[ ] Precast Steel Formwork System

II. Respondents' Information

1. What is your designation with the company?
[ ] Project Manager
[ ] Construction Manager
[ ] Project Engineer
[ ] General Manager
[ ] Production Manager
[ ] Other: ____________________

2. Respondent's experience in Precast Works? ________ Years

Section B: Production Rates of Building Progress

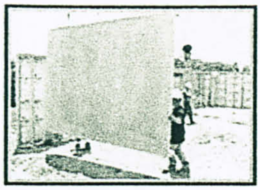
I. Production Rate Information

Please fill in the production rates in the table below using preferable units.

Precast Concrete Framing System

Activities	Production Rate	Size of each unit (activities)	Picture
Erect column include supporting false work		Column:__________	
Lift, place & join beams		Beam:__________	
Lifting & erect prefab floor units		Floor:__________	
Install topping bar (mesh)		Bar:__________	
Install edge formwork		Formwork:__________	
Pour in-situ topping		In-situ:	
Curing concrete topping		Concrete:__________	
Others:			

Precast Panel System

Activities	Production Rate	Size of each unit (activities)	Picture
Setting out			
Wall positioning & adjustment		Wall:__________	
Floor setting out		Floor:__________	
Pour concrete in-situ		Concrete:__________	
Staircase		Staircase:________	
Others:			

Precast Box System

Activities	Production Rate	Size of each unit (activities)	Picture
Setting out			
Lift, place, joint & grout box unit		Box:__________	
Pour concrete in-situ		Concrete:__________	
Staircase		Staircase__________	
Others:			

II. Additional Information

1. Overall numbers of precast production rates

    a) Numbers of days to complete a floor slab for building: ____________

    b) Numbers of days to complete one (1) storey of building in bulk: __________

2. Where do you get the precast production rates' values for your project planning & scheduling works?

[ ] Experience	[ ] Previous Related Project
[ ] Production Rate Standard	[ ] Literature
[ ] Feeling & Instinct	[ ] Other: ____________________

3. What is the methodology applied in measuring precast production rates?

____

____

III. Other Related Information

1. Do you have any production rates database for Precast Construction that is used in your project planning & scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research ?

    [ ] Yes, and it can be shared [ ] Yes, and it can't be shared [ ] No

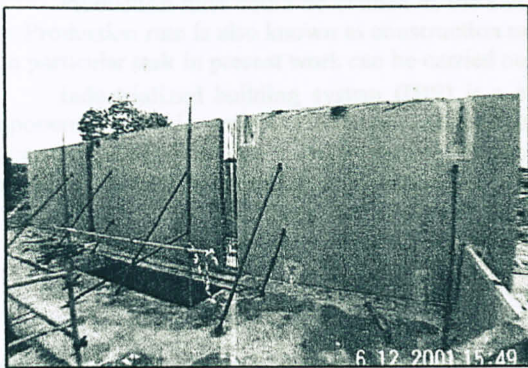
7. Please feel free to write any comment related to the topic of the study.

____

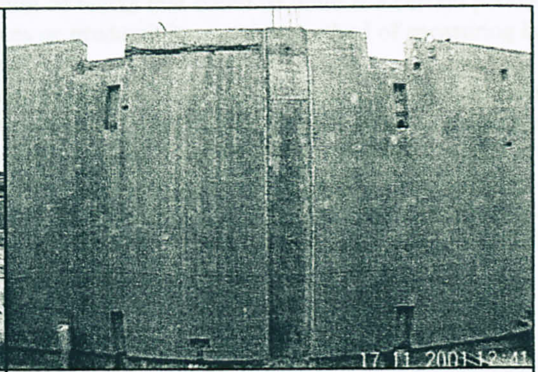
____

____

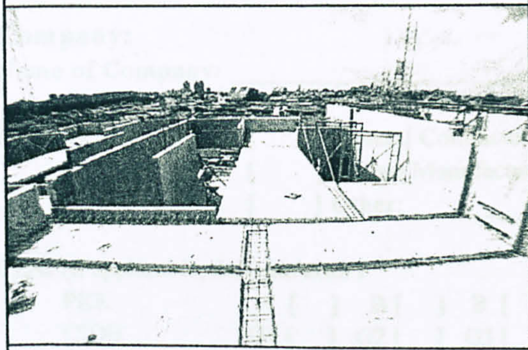
Example pictures of precast works



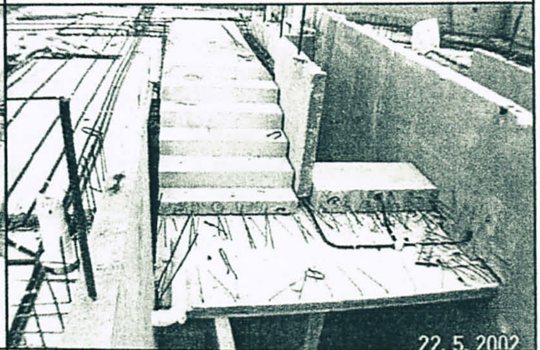
Precast walls are propped before casting of joints – proper planning is required for perfect alignment



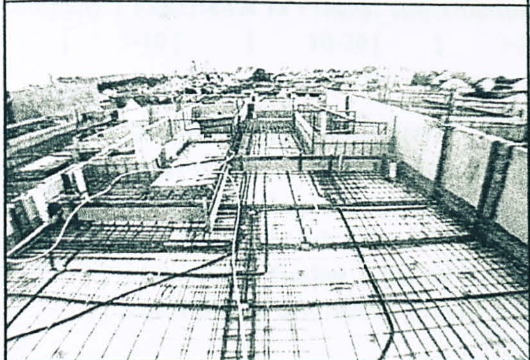
The pour strip between 2 pieces of precast walls are cast



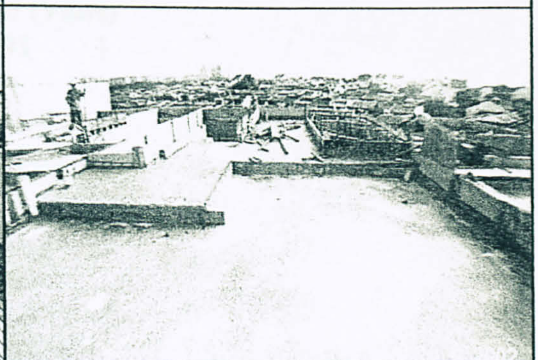
Precast planks are installed in place



Preparation for casting of landing slab to precast staircase



Preparation of welded mesh and services for cast in-situ topping



Concreting to topping

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by **16th March 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idrus).**

Development of a Database for Precast Works' Production Rates

Production rates could be defined as the amount of works that could be done at a certain period of time. Production rate is also known as construction rates or productivity rate is a method of measuring how fast a particular task in precast work can be carried out.

Industrialized building system (IBS) is a construction system that is built using pre-fabricated components. For this project, I will only concentrate on three main IBS's groups which are 1)Pre-cast Concrete Framing 2) Precast Panel System 3) Precast Box System. The objective of this research is to conduct a research to develop a database for precast works production rates.

The questionnaire is divided into 2 sections which are A and B. Please answer the questionnaire by referring to every section's instructions. To simplify and save time, point forms are encouraged.

Section A: General / Background Information

Please fill in the blanks and tick in [√] provided.

I. Company:

1. Name of Company: ______________________________

2. Type of Company: [ ] General Contractor [ ] Precast Contractor
[ ] Precast Manufacture [ ] Precast Consultant
[ ] Other: ______________(please specified)

3. Class (if applicable, for contractor):

a. PKK A [ ] B [ ] B [ ] C [ ] D [ ] E [ ] F [ ]
b. CIDB G1 [ ] G2 [ ] G3 [ ] G4 [ ] G5 [ ] G6 [ ] G7 [ ]

4. Company's experience in Precast construction? (Years)

<5 [ ] 5-10 [ ] 10-20 [ ] >20 [ ]

5. Which Precast groups are you using?

[ ] Precast Concrete Framing, Panel & Box System
[ ] Precast Steel Framing System
[ ] Precast Block Work System
[ ] Prefabricated Timber Framing System
[ ] Precast Steel Formwork System

II. Respondents' Information

1. What is your designation with the company?

[ ] Project Manager [ ] Construction Manager
[ ] Project Engineer [ ] General Manager
[ ] Production Manager [ ] Other: ____________________

2. Respondent's experience in Precast Works? ________ Years

Section B: Production Rates of Building Progress

I. Production Rate Information

Please fill in the production rates in the table below .

Precast Concrete Framing, Panel & Box System

Activities	Concrete Framing (unit/day)	Precast Panel (unit/day)	Box System (unit/day)
Erect column include supporting false work			
Lift, place & join beams			
Wall Positioning & adjustment			
Lifting & erect prefab floor units			
Install topping bar (mesh)			
Install edge formwork			
Lift, Place, joint & grout box unit			
Pour in-situ topping			
Curing concrete topping			
Staircase			

II. Additional Information

1. Overall numbers of precast production rates

a) Numbers of days to complete a floor slab for building: ___________

b) Numbers of days to complete one (1) storey of building in bulk: _________

2. Where do you get the precast production rates' values for your project planning & scheduling works?

[ ] Experience [ ] Previous Related Project

[ ] Production Rate Standard [ ] Literature

[ ] Feeling & Instinct [ ] Other: ___________________

3. What is the methodology applied in measuring precast production rates?

____

____

III. Other Related Information

1. Do you have any production rates database for Precast Construction that is used in your project planning & scheduling work? If yes, can it be shared with the research to further enhance the reliability of the research ?

[ ] Yes, and it can be shared [ ] Yes, and it can't be shared [ ] No

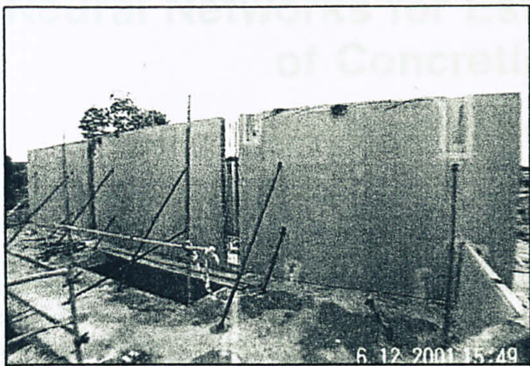
7. Please feel free to write any comment related to the topic of the study.

____

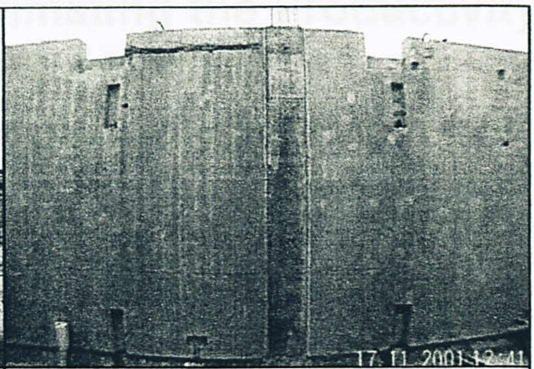
____

____

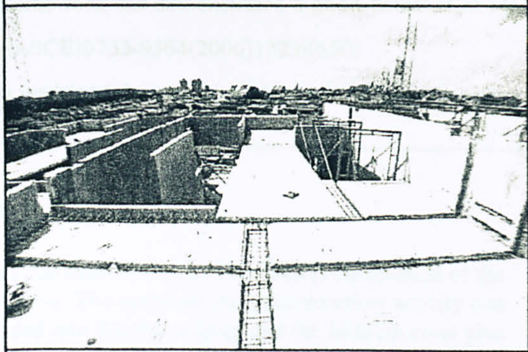
Example pictures of precast works



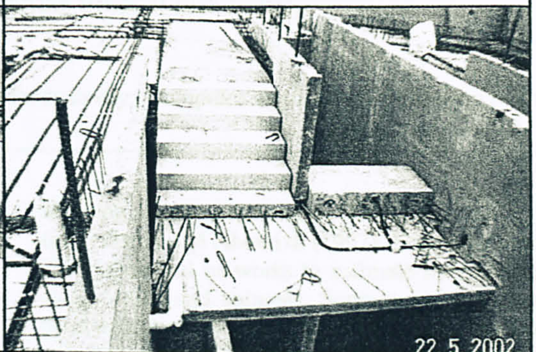
Precast walls are propped before casting of joints – proper planning is required for perfect alignment



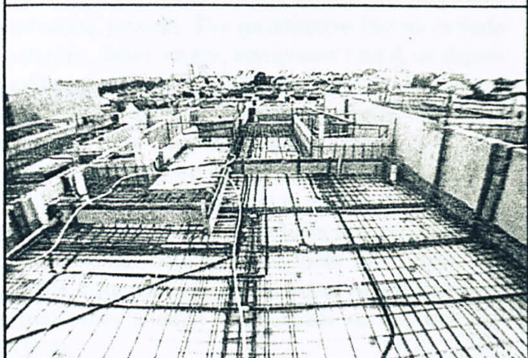
The pour strip between 2 pieces of precast walls are cast



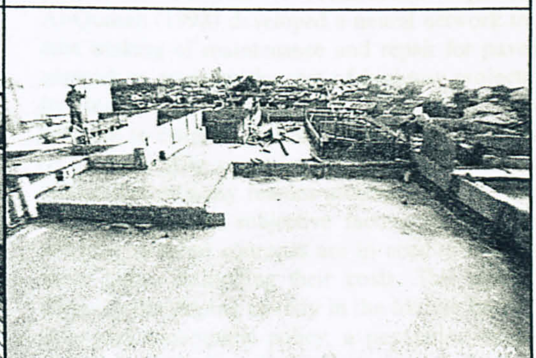
Precast planks are installed in place



Preparation for casting of landing slab to precast staircase



Preparation of welded mesh and services for cast in-situ topping



Concreting to topping

Thank you for your precious time and cooperation in completing the questionnaire. It would be highly appreciated if you could send back the questionnaire by 16th March 2008 or alternatively fax it to 05-3656716 (Attn: AP. Ir. Dr. Arazi Idrus).

Neural Networks for Estimating the Productivity of Concreting Activities

A. Samer Ezeldin[1] and Lokman M. Sharara[2]

Abstract: To overcome the variability and the impact of subjective factors on the cost of concrete-related activities in developing countries, neural networks can offer a guiding tool. In this study, three neural networks were developed to estimate the productivity, within a developing market, for formwork assembly, steel fixing, and concrete pouring activities. Eighteen experts working in six projects were carefully selected to gather the data for the neural networks. Ninety-two data surveys were obtained and processed for use by the neural networks. Commercial software was used to perform the neural network calculations. The processed data were used to develop, train, and test the neural networks. The results of the developed framework of neural networks indicate adequate convergence and relatively strong generalization capabilities. When used to perform a sensitivity analysis on the input factors influencing the productivity of concreting activities, the framework has demonstrated a good potential in identifying trends of such factors.

DOI: 10.1061/(ASCE)0733-9364(2006)132:6(650)

CE Database subject headings: Neural network; Concrete; Productivity; Computer application; Developing countries; Project management.

Introduction

Estimating is an essential tool for the successful completion of the construction process. The estimate for a construction activity can be broadly divided into the direct costs and the indirect costs plus contingency and profit. The direct costs include costs for materials, labor, and equipment. The direct costs are reached when combining the quantitative finite factors to the qualitative subjective factors in the estimating process. The quantitative factors include unit prices of materials, labor wages, equipment rental, or depreciation. The qualitative subjective factors are more difficult to determine. They include, among others, productivity rates, and associated construction risks (Gould 2002).

Experienced estimators rely on their personal expertise to incorporate the effect of qualitative factors in their estimate. Less experienced estimators could benefit from tools that would incorporate such effects. Neural networks are tools that attempt to mimic the human brain functions. Like the brain, neural networks learn from past trials; they attempt to generalize on the data provided (Harvey 1994).

The usage of neural networks has been gaining a widespread attention in the construction industry to aid in many applications. Portas and Abourizk (1997) designed a system that utilizes artificial neural networks to estimate formwork productivity for slabs, walls, and columns. Sonmez and Rowings (1998) developed neural networks to estimate productivity values of formwork assembly, concrete pouring, and concrete finishing. Arditi and Tokdemir (1999) attempted to create a neural network that would predict the outcome of construction litigation. Alsugair and Al-Qudrah (1998) developed a neural network to aid in the decision making of maintenance and repair for pavements. A neural network to estimate the cost of highway projects was developed by Hegazy and Ayed (1998). Li et al. (1999) developed a neural network to estimate markup for bids in construction projects.

In developing countries the construction environment is much riskier due to many reasons among which are the variability and the impact of the subjective factors on direct costs. Engineers working in these countries are in need of effective tools to help them better estimating their costs. This study is focusing on Egypt, a developing country in the Middle East with an emerging reformed economical policy, a population of about 70 million, and an increasing need of infrastructure and industrial projects. In Egypt, the concrete activities, usually, constitute a major bulk of the construction projects. An attempt is made to illustrate the usage of neural networks to estimate labor's productivity in concrete-related construction activities in this local market. The attempt is based on collecting data from expert construction engineers handling such activities in actual projects.

Methodology

The objective of this study is to develop neural networks capable of predicting the productivity rates of forms assembly, steel fixing, and concrete pouring while incorporating both quantitative

[1]Associate Professor, Dept. of Construction Engineering, The American Univ. in Cairo, 113 Kasr El Aini St., P.O. Box 2511, Cairo 11511, Egypt (corresponding author). E-mail: aezeldin@aucegypt.edu

[2]Graduate Student, Dept. of Construction Engineering, The American Univ. in Cairo, 113 Kasr El Aini St., P.O. Box 2511, Cairo 11511, Egypt.

Note. Discussion open until November 1, 2006. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this technical note was submitted for review and possible publication on May 2, 2005; approved on October 19, 2005. This technical note is part of the *Journal of Construction Engineering and Management*, Vol. 132, No. 6, June 1, 2006. ©ASCE, ISSN 0733-9364/2006/6-650–656/$25.00.

Survey on Concrete Works Productivity

The Purpose of this survey is to asses the productivity of concrete works putting in consideration various factors and conditions that may affect this productivity.

Participant Data

Form Filled By __________ Position __________
Company __________ Date of Survey __________

Project Data

Project Name __________ Owner __________
Project Location __________ Consultant __________
Project Description __________ Contractor __________

General Data

Structural Element(s) Under Consideration __________
Quantity of Concrete __________ m3
Duration of the Construction (Formwork, Steel Fixing, & Concrete Pouring) __________ days
Temperature Conditions O Cold O Moderate O Hot
Working Conditions O Mild O Moderate O Harsh

Form work Assembly Data

Crew Size __________ no. Duration __________ days
Type of form work __________ Type of Falsework __________
How do you classify the supervision over the labor? O Little O Adequate O Strict
How do you classify the labor skills? O Unskillful O Adequate O Skillful
Did labor stay overtime significantly? O Yes O No
Complexity of the Task O Typical O Complex
Accessibility of Materials O Easy O Moderate O Hard
Degree of Repetition O None O Moderate O Repetitive

Steel Fixing Data

Crew Size __________ no. Duration __________ no.
Quantity __________ tons
How do you classify the supervision over the labor? O Little O Adequate O Strict
How do you classify the labor skills? O Unskillful O Adequate O Skillful
Did labor stay overtime significantly? O Yes O No
Complexity of the Task O Typical O Complex
Accessibility of Materials O Easy O Moderate O Hard
Degree of Repetition O None O Moderate O Repetitive

Concrete pouring

Pouring Crew Size __________ no Duration __________ no
What type of pouring method was used ? O Ready Mixed O Batch Plant O Traditional Mixer
How do you classify the supervision over the labor? O Little O Adequate O Strict
How do you classify the labor skills? O Unskillful O Adequate O Skillful
Did labor stay overtime significantly? O Yes O No
Complexity of the task O Typical O Complex
Accessibility to Materials O Easy O Moderate O Hard
Degree of Repetition O None O Moderate O Repetitive

General Comments

____

____

Fig. 1. Survey form of productivity of concrete works

and qualitative factors. In order to achieve such an objective a systematic methodology had to be implemented and followed.

Survey Form

Literature review was first used to develop an initial survey form that includes the factors that affect the productivity rates of concreting activities (Chao and Skibniewski 1994; Halligan et al. 1994; Ersoz 1999; Thomas et al. 1999). This initial survey form was discussed during personal interviews with five experienced project managers. These project managers had each a minimum of 15 years of experience with residential, commercial, and industrial projects. This step was performed in order to adjust the fac-

Table 1. Factors Considered Affecting Corresponding Neural Networks (NN)

Factors	Formwork assembly NN	Steel fixing NN	Concrete pouring and finishing NN
Structural element	•	•	•
Concrete quantity	•	—	•
Steel quantity	—	•	—
Crew size	•	•	•
Falsework type	•	—	—
Formwork type	•	—	—
Pouring method	—	—	•
Supervision	•	•	•
Labor skills	•	•	•
Overtime	•	•	•
Task complexity	•	•	•
Material accessibility	•	•	•
Degree of repetition	•	•	•
Temperature conditions	•	•	•

tors found in the literature to the local market. The survey form was revised and finalized based on the input of these experts. The final survey form on the productivity of concrete works is shown in Fig. 1.

Data Gathering

The data gathering included both qualitative and quantitative data. The latter type of data do not cause much noise for the neural networks as it is based on documented record from the same market at the same time interval. The qualitative type of data on the other hand has a subjective nature because it mainly depends on the expertise and opinion of the participants. To minimize the level of noise of such data, the writers opted to use the approach of formal interviews using a common checklist. This approach was adopted to obtain better and consistent feedbacks from the interviewees. A total of 18 participants, different from the original five experienced project managers, and working in six different projects, were interviewed to collect 92 survey forms. The participants were construction or site engineers having 5 to 10 years of experience with concrete construction activities in the local market. Some participants were working in the same project; however, each participant was selected such as he/she would be working independently of other participants (Company, location, etc.).

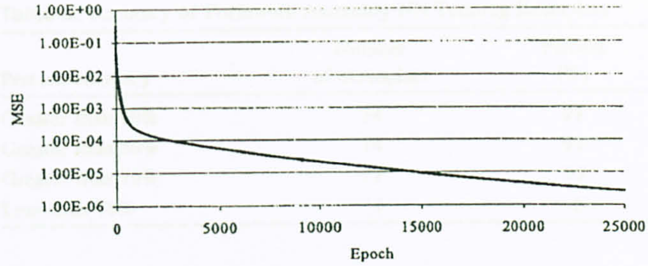


Fig. 2. MSE versus epochs for formwork assembly NN

Table 2. Choice of Numerical Conversions

Factor	Choice				
Structural element under consideration	PC Footing 1	RC Footing 2	Raft 3	Horizontal 4	Vertical 5
Falsework	Wood 1	steel 0	— —	— —	— —
Formwork type	Wood 2	plywood 1	Steel 0	— —	— —
Pouring method	Traditional mixer 2	Ready mixed 1	Batch plant 0	— —	— —
Supervision	Little 2	Adequate 1	Strict 0	— —	— —
Labor skills	Little 2	Adequate 1	Skillful 0	— —	— —
Overtime	No 1	Yes 0	— —	— —	— —
Task complexity	Typical 1	Complex 0	— —	— —	— —
Material accessibility	Easy 2	Moderate 1	Hard 0	— —	— —
Degree of repetition	None 2	Moderate 1	Repetitive 0	— —	— —
Temperature conditions	Cold 2	Moderate 1	Hard 0	— —	— —
Working conditions	Mild 2	Moderate 1	Harsh 0	— —	— —

Table 3. Arrangement of Hidden Neurons

Parameters	Formwork NN	Steel NN	Concrete NN
Hidden layers	2	2	2
Hidden neurons	70	30	20
Neuron arrangement	35/35	15/15	10/10

Three main characteristics were considered when selecting the projects included in the study. First, the project under consideration must include a significant amount of concrete work with available documented data. Second, the construction methods used in performing the concrete activities were similar and executed within a period of 1–2 years from the time of obtaining the data. Third, the concrete elements included in the data should be representative of similar elements in the market. As such, the concrete elements chosen were plain concrete foundation, reinforced concrete isolated footings, rafts, slabs on grade, elevated slabs, beams, columns, and shear walls. Advanced forming techniques such as slipforms, climbing forms, and lift slabs were excluded. Normal strength concrete (less than 40 MPa) was used in all projects. The six projects selected for the study included commercial, industrial, and residential projects.

Data Processing

The data processing was conducted in three steps. The first step consisted of entering the data from the surveys into a main table. The main table was divided into five areas. Area one dealt with general data. The inputs of these data fields were the same for formwork assembly, steel fixing, and concrete pouring networks. These inputs included: project name; project location; affiliation of the participant; structural element under consideration; quantity of concrete; temperature conditions; and working conditions. Areas two, three, and four were three individual areas, each containing factors affecting a specific one of the three concreting activities included in the study. Each area was used to develop a unique neural network for that activity. Table 1 illustrates the factors considered for developing each of the neural networks. Area five included the desired productivity rate in days for each of the three main activities.

The second step in the data processing was the conversion of data into numeric values and the formulation of the individual set for each neural network. If the input data fields available in the survey were numbers, then they were directly entered into the neural networks without manipulations or calculations. Each numerical data field was linked to its corresponding position in its matrix, and simply transferred there. Data fields of that nature were concrete quantity, steel quantity, and crew size. On the other hand, if the input data were in text form, it needed to be converted from text format into numerical form in order for the neural network to utilize it in its computations. Table 2 shows the input factors, the text choices available for each of them, and the corresponding numerical form used by the neural networks. The numbers assigned for each input choice shown in the table decreased, as the choice became more demanding for the productivity. If/then statements were used along with the text form inputs to assign the appropriate numerical values and to control their positioning.

Table 4. Training and Testing Data Sets

	Total data set	Training data set	Testing data set
Formwork assembly NN	90	81	9
Steel fixing NN	80	72	8
Concrete pouring NN	92	84	8

Table 5. Accuracy of Formwork Assembly NN Training Exemplars

Percent accuracy	Number of exemplars	Percent (%)
Greater than 90%	74	91
Greater than 80%	74	91
Greater than 70%	77	95
Less than 70%	4	5

The output productivity data fields actually represented the desired output the network would work to achieve. Calculations as man days per unit would be produced (Portas and Abourizk 1997). Each activity matrix was linked to the main survey table with an equation to compute productivity. The equations were as follows:

$$\text{Formwork productivity (man days/m}^3) = \text{Formwork crew size (man)} \times \text{Formwork assembly duration (day)/concrete quantity (m}^3) \quad (1)$$

$$\text{Steel fixing productivity (man days/ts)} = \text{steel crew size (man)} \times \text{steel fixing duration (day)/steel quantity (ts)} \quad (2)$$

$$\text{Concrete pouring productivity (man days/m}^3) = \text{pouring crew size (man)} \times \text{concrete pouring duration (day)/concrete quantity (m}^3) \quad (3)$$

These equations were used because they include the man hour as input. Another productivity equation (for example meter^3/day) would have the crew size embedded in it rather than being clearly spelled out.

The third step in the data processing included randomizing records and normalizing data. This step was performed using features included in a commercial computer program used during the study (NeuroSolutions 4 2001). As the data were fed into the main survey table, it was entered from the surveys at hand. To avoid the monotony that could arise from this situation, randomization or shuffling of the records was required. The randomization improved the generalization capability of the network and allowed for smoother convergence. Normalizing data was another manipulation that was carried out on the data using the commercial software. The process converted the numbers available in each matrix to values between zero and one. Such scaling would allow the neural networks to converge faster and later to generalize better outputs.

Network Architecture

The network architecture refers to the makeup of the elements of the neural networks, their organization, and the parameters

Table 6. Accuracy of Steel Fixing NN Training Exemplars

Percent accuracy	Number of exemplars	Percent (%)
Greater than 90%	70	97
Greater than 80%	71	99
Greater than 70%	71	99
Less than 70%	1	1

that affect them. The commercial computer program was used to develop, train, and tests the neural networks (NeuroSolution 4 2001).

Numerous network architectures were developed, trained, tested, and compared for the appropriate selection to be made. The following guidelines were followed.

1. The number of neurons should be sufficient for the network to converge yet they should not be exaggerated to make the network memorize.
2. The number of hidden layers should be minimized to avoid a longer training period for the neural network.

The decision making process of the appropriate network architecture was made according to the mean squared error (MSE). A detailed discussion of the parameters that affect the network architecture follows.

Parameters of Network Architecture

The learning algorithm used for all the neural networks was the feed-forward back propagation learning algorithm where each layer feeds the layer succeeding it directly.

The transfer function utilized in all three neural networks was the hyperbolic tan function (tanh). The sigmoid function, linear function, and other functions available on the software were also tested several times, producing less accurate results.

Online training occurs when the error is accumulated back through the network after each training fact or exemplar. Batch training occurs when the total error is accumulated back through the network for the whole training data set. The results indicated that batch training produced smoother convergence.

The number of epochs refers to the number of training cycles the network should execute. The neural networks were run for epochs ranging from 1,000 to 50,000. However, the 25,000 epoch was selected because it had suitable training time and acceptable convergence. Below 25,000 epochs the network had difficulty converging. Above 25,000 epochs, on the other hand, the training time was delayed significantly. Average training time for the neural networks at hand ranged between 10 and 40 min, depending on the amount of neurons available.

Selecting the acceptable number of hidden layers and corresponding neurons entailed generating numerous trial neural networks (NNs) with different numbers of hidden layers and neurons. The number of tried neural networks for each of the concrete activities was 22, 15, and 51 for formwork assembly NN, steel fixing NN, and concrete pouring NN, respectively. The variables were the number of neurons and hidden layers. The final selection was made based on reaching acceptable values for three types of MSE, namely; training MSE, training input/output MSE, and testing input/output MSE. The training MSE is the average of the squares of the difference between the desired and predicted outputs for every neuron in the neural network. It is calculated for every epoch during the run of the network. In other words a plot for the value of the training MSE at every epoch may be calculated. Fig. 2 shows a typical curve for the training MSE versus the epochs. The training input/output MSE for the network is the average of the squares of the difference between the desired and predicted outputs for the training data set. The testing input/output MSE is the average of the squares of the difference between the desired and predicted outputs for the testing data set. Unlike the training MSE, the training input/output MSE and the testing input/output MSE are calculated after the network stops the training process. They use the final weights that the network has calculated to predict their outputs. The predicted outputs and the desired ones produce the input/output mean squared errors.

Table 7. Accuracy of Concrete Pouring NN Training Exemplars

Percent accuracy	Number of exemplars	Percent (%)
Greater than 90%	35	38
Greater than 80%	46	50
Greater than 70%	55	88
Less than 70%	29	13

Table 8. Accuracy of Formwork Assembly NN Testing Exemplars

Percent accuracy	Number of exemplars	Percent (%)
Greater than 90%	4	44
Greater than 80%	6	67
Greater than 70%	6	67
Less than 70%	3	33

The target ranges for these MSE were 10^{-6}, 10^{-4}, and 10^{-1} for training MSE, training input/output MSE, and testing input/output MSE, respectively. These ranges were selected to keep running times at less than 40 min for 25,000 epochs.

The mean squared error equation states

$$\mathrm{MSE}=\frac{\sum_{j=1}^{P}\sum_{i=1}^{N}(d_{ij}-y_{ij})^2}{NP} \tag{4}$$

where MSE=mean squared error; P=number of output processing elements; N=number of exemplars in the data set; d_{ij}=desired output for exemplar i at processing element j; and y_{ij}=actual output for exemplar i at processing element j.

Table 3 shows the selected number of hidden layers and corresponding neurons for each of the three neural networks.

Another important issue is the division of the data set into training and testing sets. The training data set is responsible for the learning process of the network. The testing data set, however, has data the network did not use in its training calculations. The testing data measures the generalizing capability of the network. There is no rule dictating what percentage exactly is allocated to the training set and the testing set. However, it is important to have sufficient training data for the network to converge. The process of training and testing is dynamic and continuous, which means with the availability of more data further training and testing may be performed. To determine an appropriate amount of training and testing data, two divisions were considered. The first was 90% of the data for training and 10% for testing. The second was 50% of the data for training and 50% for testing. After initial testing, it was apparent that the results of the first division were

Table 9. Accuracy of Steel Fixing NN Testing Exemplars

Percent accuracy	Number of exemplars	Percent (%)
Greater than 90%	3	38
Greater than 80%	5	63
Greater than 70%	6	75
Less than 70%	2	25

more accurate. As such, the study adopted the division of 90% of the data for training and 10% for testing. Table 4 shows the division for the three neural networks.

In summary, the selected networks had 90% training and 10% testing divisions. All neural networks used the feed-forward and back-propagation algorithm with the momentum learning rule. Batch training was used for 25,000 epochs with the hyperbolic tan transfer function.

Neural Networks Model Validation

After the network trains for the designated number of epochs, the network freezes the weights it has reached. Calculations performed from this point on will be using those weights. A validation of the neural networks is required to determine the extent of the learning and generalization of the neural networks. To proceed with comparison between the desired productivity and the predicted productivity it is crucial to determine a level of accuracy. The capability of the networks to produce accurate results is obtained by determining the percentage of exemplars meeting or exceeding a preset accuracy level. Three levels of accuracy were selected in this study to demonstrate the credibility of the developed networks. These levels were 70, 80, and 90%. It is worth mentioning that the level of accuracy should be regarded as an indicator, with the available data, for the capability of the training data sets to converge and for the testing data sets to generate values

Prediction of Training and Testing Data Sets

Tables 5–7 indicate the accuracy of the training data sets for the formwork assembly, steel fixing, and concrete pouring neural networks, respectively. The accuracy of the training exemplars indicates that the networks have adequately converged. At 70% accuracy level, the networks produced predicted productivity of 95, 99, and 88%, for the formwork NN, the steel fixing NN, and the concrete pouring NN, respectively. At 90% accuracy level, these values dropped to 91, 97, and 38%. The concrete pouring NN generated the lowest number of acceptable exemplars.

The results of the testing data set are actually an indication of the generalization capability of the neural networks. The inputs are run forward through the network using the weights calculated during the training phase. The testing exemplars indicate that the network has developed reasonable generalization capabilities.

Table 10. Accuracy of Concrete Pouring NN Testing Exemplars

Percent Accuracy	Number of exemplars	Percent (%)
Greater than 90%	3	42
Greater than 80%	4	55
Greater than 70%	7	65
Less than 70%	1	35

Tables 8–10 indicate the accuracy of the predicted data for the test sets. At the 70% level of accuracy, the percentages of acceptable exemplars were 67, 75, and 65% for formwork assembly, steel fixing, and concrete pouring, respectively. However, at 90% accuracy level, these values dropped to 44, 38, and 42%. Again, the concrete pouring NN generated the lowest number of acceptable exemplars.

The writers acknowledge that a larger set of data for training and/or for testing would enhance the percentages of acceptable exemplars at all accuracy levels and as such the confidence in the outputs. At the same time, it can be stated that the developed framework of neural networks has demonstrated learning and generalizing capabilities.

Sensitivity Analysis

Sensitivity analysis is conducted by varying each input, while keeping all the other inputs constant at their mean values, and calculating the corresponding output. The achieved results do not form productivity models; however, they provide an indication of the manner with which productivity is affected.

The effect of some significant input factors on productivity, as obtained from the networks runs, is summarized below. Productivity may decrease by up to 65% for hot weather conditions (more than 35°C). A change in productivity by ±20% may result, depending on the degree of labor supervision. An average of 50% increase in productivity may result with better labor skills. Productivity may double for typical tasks. An increase in productivity value of up to 30% may result, depending on the degree of material accessibility. Up to a 20% increase in productivity may result with repetitious tasks.

Conclusions

For the local market of a developing country, a framework to predict the productivity of concreting activities using neural networks was designed, developed, trained, and tested. The results show that the networks adequately converged and have reasonable generalizing capabilities.

The developed framework was also used to perform a sensitivity analysis on the input factors influencing the productivity of concreting activities. The framework has demonstrated a good potential in identifying trends of such factors.

References

Alsugair, A. M., and Al-Qudrah, A. A. (1998). "Artificial neural network approach for pavement maintenance." *J. Comput. Civ. Eng.*, 12(4), 249–255.

Arditi, D., and Tokdemir, O. B. (1999). "Comparison of case-based reasoning and artificial neural networks." *J. Comput. Civ. Eng.*, 13(3), 162–169.

Chao, L., and Skibniewski, J. (1994). "Estimating construction productivity: Neural-network-based approach." *J. Comput. Civ. Eng.*, 8(2), 234–251.

Ersoz, H. (1999). "Discussion of neural network model for estimating construction productivity." *J. Constr. Eng. Manage.*, 125(3), 211–212.

Gould, F., *Managing the construction process: Estimating, scheduling, and project control*, 2nd Ed., Prentice–Hall, Upper Saddle River, N.J.

Halligan, D. W., Demsetz, L. A., Brown, J. D., and Pace, C. B. (1994).

"Action-response model and loss of productivity in construction." *J. Constr. Eng. Manage.*, 120(1), 47–64.

Harvey, R. L. (1994). *Neural network principles*, Prentice–Hall, Englewood Cliffs, N.J.

Hegazy, T., and Ayed, A. (1998). "Neural network model for parametric cost estimation of highway projects." *J. Constr. Eng. Manage.*, 124(3), 210–218.

Li, H., Chen, L. Y., and Love, P. E. D. (1999). "ANN-based mark-up estimation system with self-explanatory capacities." *J. Constr. Eng. Manage.*, 125(3), 185–189.

NeuroSolutions 4 (2001), NeuroDimensions Inc., Gainesville, Fl.

Portas, J., and Abourizk, S. (1997). "Neural network model for estimating construction productivity." *J. Constr. Eng. Manage.*, 123(4), 399–410.

Sonmez, R., and Rowings, J. E. (1998). "Construction labor productivity modeling with neural networks." *J. Constr. Eng. Manage.*, 124(6), 498–504.

Thomas, R. H., Riley, D. R., and Sanvido, V. E. (1999). "Loss of labor productivity due to delivery methods and weather." *J. Constr. Eng. Manage.*, 125, 39–46.

ISSUES AND CHALLENGES IN THE IMPLEMENTATION OF INDUSTRIALISED BUILDING SYSTEMS IN MALAYSIA

Ahmad Baharuddin Abd. Rahman, Wahid Omar
Faculty of Civil Engineering, Universiti Teknologi Malaysia,
Skudai, Johor, MALAYSIA

ABSTRACT: The Industrialized Building Systems (IBS) Roadmap 2003-2010 published by the Construction Industry Development Board (CIDB) outlines several well-thought strategies and aggressive steps to promote the use of IBS in Malaysia. The government is taking the leading role to persuade the construction industry to engage a more systematic approach and methodology in construction. It is a strategic change in the construction industry and the effort started in 1998. Besides the aim to gradually reduce the dependency on foreign labour and saves the country from losing out foreign exchange, IBS provides the opportunity for the players in the construction industry to develop a new image of the construction industry to be at par with other manufacturing industries such as car and electronic industries. With the present conventional methods of construction, the industry is always associated with many unprofessional practices. The adoption of IBS promises to elevate every level of the industry to a new height and image of professionalism. By adopting IBS, efficient, clean, safe, professionally managed and handled by professionals and workers with relevant skills, proper coordination and management, precision, innovative and quality will be appeared as new attributes to be associated with the construction industry. The industry players are expected to venture internationally and one of the pre-requisite to compete globally is to offer quality, efficient and professional services and again IBS can be an excellent option. Although some of IBS have been introduced in Malaysia as early as in 1960's, the industry as a whole seems quite reluctant to exploit the use of IBS. A recent survey carried out on the use of IBS in Malaysia reveals some of the issues and challenges, which require attention from different parties.

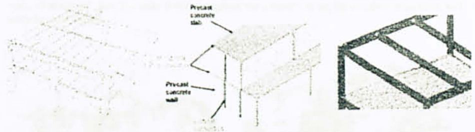
1.0 Introduction

Industrialised building system (IBS) is a construction system that is built using pre-fabricated components. The manufacturing of the components is systematically done using machine, formworks and other forms of mechanical equipment. The components are manufactured off-site and once completed will be delivered to construction sites for assembly and erection.

In Malaysia, Construction Industry Development Board (CIDB) has classified the IBS system into 5 categories as follows:

i). precast concrete framed buildings
ii). precast concrete wall buildings
iii). reinforced concrete buildings with precast concrete slab
iv). steel formwork system
v). steel framed buildings and roof trusses.

In this paper, however, only three systems of IBS are discussed namely the skeletal precast framed , precast wall and steel framed structures (see Figure 1).



(a). Skeletal precast concrete framed structure (b). Precast concrete Wall (c). Steel framed structure
Figure 1

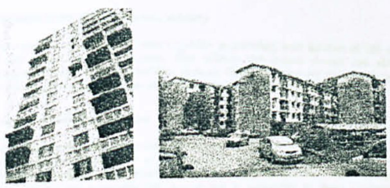
The IBS systems as mentioned above are not new in Malaysia. For example, precast wall system has been adopted in Malaysia as early as in the late 60s. Even though the IBS systems have been in existence for a long time but there are still many unresolved issues. Some of the issues are the ability of the industry players to equip with necessary technical knowledge in order to adopt IBS in their projects. Examples of this lacking are clearly reflected in the quality of the completed projects and there are situations where IBS could not be continued due to unavailability of relevant technical experts. This paper discusses those issues and suggests appropriate approach in overcoming them.

2.0 Issues of IBS

2.1 IBS as mass construction method.

The term 'IBS' is often misinterpreted with negative meaning as it is always linked with industrialized buildings that were built in1960s. These buildings are normally associated with pre-fabricated mass construction method, low quality buildings, leakages, abandoned projects, unpleasant architectural appearances and other drawbacks. Due to the poor architectural design, the old pre-fabricated buildings have given the public, bad impression about precast concrete.

There have been quite a number of cases where the use of IBS had lead to such drawbacks. For example, in the case of Pekeliling Flats in Kuala Lumpur and Taman Tun Sardon, Gelugor, Penang (see Figure 2). These two early pre-fabricated flats were constructed in mass to produce low cost accommodation for lower income groups. In the case of Taman Tun Sardon, the IBS precast system was designed by British Research Establishment, UK for low cost housing in tropical countries. However, the design was very basic and not considering the aspect of serviceability such as the need for wet toilets and bathrooms. Lacking in this design consideration leads to problems of leakage that becomes the common issue with precast buildings. In addition, in many cases the low cost housings are not maintained properly, thus contributing further to the poor image of IBS buildings.



(a). Pekeliling Flats, Kuala Lumpur (b). Taman Tun Sardon, Gelugor, Penang
Figure 2

2.2 Lack of involvement from small contractors

From the survey it is found that many small contractors are reluctant to adopt IBS system and prefer to continue using the conventional method of construction. This is due to the fact that small contractors are already familiar with the conventional system and for them the technology suit well with small scale projects and therefore not willing to switch to mechanized based system. Furthermore small contractors lack financial backup and are not able to set up their own manufacturing plants as it involves very intensive capital investment. In this case, financial issues become the main obstacle for small contractors to move forward with the IBS system. On the other hand, however, many big players in IBS industry have shown good track records in building successful IBS projects. This shows that IBS is a feasible system provided the parties involved have the capabilities to carry out the work related to IBS such as analysis, design and manufacturing of IBS components.

2.3 Lack of knowledge and exposure to IBS technology

Lack of knowledge in structural analysis and design of pre-fabricated components among civil engineers and those related to construction discourages further the implementation of IBS system. Unlike steel structures, the subject of precast concrete design is normally not delivered to undergraduate students in many universities. As a result, many junior engineers are not really familiar with the precast concrete technology as compared to structural steelwork.

Knowledge in construction technology is equally important. There are cases, where building projects are awarded and constructed using IBS system but were carried out with many difficulties. The most common problems encountered are improper assembly of the components that normally involved the beam-to-column and column-to-base connections. These problems arise due to the fact that the parties involved in the construction underestimate the important of accuracy in setting out the alignment and levelling of the bases. Basically, accurate levelling and alignment of the bases are the two most important aspects for the successful rapid erection of precast concrete components.

Other related technical issues are lack of knowledge capability in designing the details of ties and connections of the pre-fabricated components particularly in precast concrete construction. Poor connection system may cause problem to site work such that the connections cannot be joined properly due to poor construction details (see Figure 3).

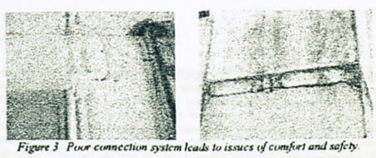


Figure 3 Poor connection system leads to issues of comfort and safety.

In the case of steelwork structures, there are many cases where buildings were designed to imitate the conventional reinforced concrete structural system. This concept results in exposed steel beams and columns. Eventually this invites many serviceability problems such as leakage (see Figure 4). Rain water can easily seep into the internal building through the joint between the wall and steel beam. Dampness leads to corrosion to the lighting system and the steel beam.

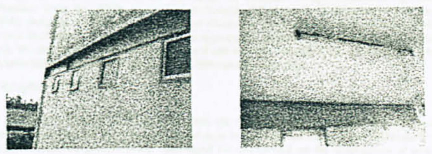


Figure 4 Steel beam should not be exposed to as in the case of concrete beam.

3.0 Successful Implementation of IBS Projects

With the advanced knowledge in computer aided design, IBS buildings can be designed and visualised analytically prior to the actual construction. The 3-dimensional drawings can be developed to provide accurate component dimensions and hence ensure buildability. Erection and construction procedures can also be simulated and properly planned with the use of computer softwares. Feasibility studies on the different building systems can be performed without incurring much cost. Problems during construction can also be observed and predicted. Any rectifications to the component design can be done before the manufacturing process. These computer tools contribute to a well-planned and systematic IBS system.

In relation to the advancement in computer-aided design, IBS buildings built in Malaysia in the 1990s have shown significant improvement in terms structural performance and architectural aspects. Some of these structures have become the showcases and even the icon of the country.

One good example is the Brickfields Secondary School 1. The school is located in a busy and limited access site. With such construction constraints and to expedite construction period, a building system utilising about 75% of pre-fabricated components of precast concrete beams, columns, hollow core slabs and solid planks were adopted. The precast concrete skeletal framed IBS system is also widely used in many other projects. Figures 6 and 7 show the precast concrete buildings that were built using precast concrete components of beams, columns and slabs.

Figure 5 During and after construction of Brickfields Secondary School (I), Kuala Lumpur.

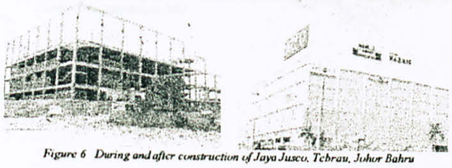


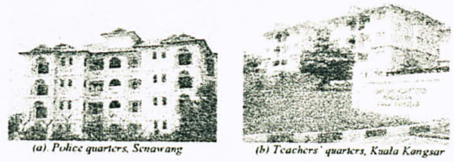
Figure 6 During and after construction of Jaya Jusco, Tebrau, Johor Bahru

(a). Subang Square, Subang Jaya *(b). Millennium Hall, Seberang Prai*

Figure 7

Another successful examples of IBS systems using precast concrete load bearing wall system are Senawang Police Quarter (see Figure 8(a)), teachers' quarters in Kuala Kangsar (see Figure 8(b)) and government quarters in Putra Jaya (see Figure 8(c)). A total of 10,000

units of teachers' quarters were built throughout the country using the standard structural and architectural design.



(a). Police quarters, Senawang *(b) Teachers' quarters, Kuala Kangsar*

(c). Government quarters, Putrajaya.

Figure 8

In the case of steel structures, there are also many successful IBS projects. Figure 9 shows the KLCC convention centre, an icon building in the prestigious Kuala Lumpur city centre. The building was built using a combination of prefabricated steel roof truss with composite steel deck flooring system.

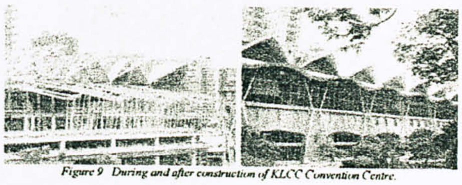


Figure 9 During and after construction of KLCC Convention Centre.

4.0 Challenges in the IBS construction industry

It can be seen that contractors that have capability in providing total solution of IBS system carried out many successful projects. This reflects that proper desigo and planning considerations promise good IBS building systems. However, there are many challenges to achieve this target and the main ones are described in sections 4.1 to 4.5.

4.1 Designing a Feasible IBS System

IBS system if properly designed can deliver a more efficient construction process due to many advantages such as greater speed of construction, simpler construction process, reduced environmental impact and reduce reliance on traditional labours. Therefore the challenge is to provide a feasible and innovative IBS system that is acceptable to those involved with construction as well as the users.

In order to achieve a feasible IBS system, the aspect of standardization should be incorporated in designing the system. The standardisation can include the use of standard connections, standard beam and column sizes. Standardisation of components may be incorporated to reduce the cost of manufacturing. By implementing standardization, many errors in production or erection due to variability can be reduced. Standardisation may lead to improvement in quality, decrease variability and increase the ease of manufacturing.

In this case, the challenging aspect related to a feasible system is the manufacturing of the components. For example, the steel mould used to form beams and columns must have high degree of precision to produce accurate and consistent dimensions of width, breadth and length and other related dimensions. The mould should be of high quality with enough durability and strength and not easily becomes dented or buckled during compaction of the concrete. In the case of mechanical connections, the built in connection accessories to be cast in the concrete component, must be located precisely prior to concreting. Similarly any sleeves or opening in the component must be done accurately.

4.2 Investment on Heavy Equipment for Mechanized Construction System

The successful IBS construction system has some degree of dependency to heavy and special equipment such as cranes. The high initial cost in setting up the manufacturing plant as well as the cost of transportation has reduced the margin of profit. It has been noticed that despite all the advantages of adopting IBS, a significant portion of the construction industry players still has a biased perception on IBS system. It is admitted presently that switching to IBS would not guarantee significant savings in the cost especially with the small volume of buildings constructed. However, IBS has demonstrated that the savings in the construction time is able to compensate the higher construction cost incurred.

4.3 Awareness

In order for IBS system to be understood and used widely, the challenge is to create mechanism of awareness. Many contractors and even engineers are not well aware of the IBS system and not involved with the use of any IBS system in their construction methods. Therefore, in order to create awareness among practicing engineers and contractors, campaign to reassure that IBS systems are able to provide fast, economical and high quality products should be carried out. The awareness campaigns may include seminars and short courses. For example, CIDB in collaboration with universities, manufacturers and professional bodies have carried out extensive seminars and roadshow to give exposure to contractors and engineers about the IBS system. Also, hands-on trainings in specialised works such as operating cranes

and welding works are also conducted to provide specilised and trained workers in the IBS industry.

4.4 Knowledge

Specialized and additional engineering knowledge will be required to design, manufacture and constrict a good IBS system. All parties involved from designers to erectors must have enough knowledge about the pre-fabricated component based construction. In terms of design, the engineers must have competent knowledge in analysis and design. In the construction field, the contractors and site engineers must have enough knowledge on the safe and accurate methods of erecting and assembling loose components into a global structure.

At university level, the students should be taught structural design principles, material technologies and construction practices related to IBS system such as precast concrete structures. Some local universities are currently improving their curriculum by adding new topics related to IBS in the existing syllabus. For example subjects related to precast concrete design and construction are also offered as elective for final undergraduate and graduate students. Apart from that, testing and research have to be conducted to prove feasibility of design. Knowledge gained from advanced research may elevate the level of understanding on the behaviour of IBS structure and consequently the level of confidence.

Engineers with good technical knowledge in analysis, design, manufacturing and construction have the ability to produce systematic IBS systems. If the components are skillfully designed, erection can be carried out efficiently. Furthermore, complying with good practices in design and construction leads to high quality precast concrete structures. In this aspect, the challenge is to produce many good and reliable manufacturers and erectors with such knowledge capabilities to be part of the IBS construction team.

4.5 Adoption of IBS System

The government through CIDB has embarked the IBS Roadmap 2003-2010 that outlines several well-thought strategies and aggressive steps to promote the use of IBS in Malaysia To facilitate further, the goverment has encouraged the use of IBS for the construction of new government quarters. Contractors adopting the IBS system are given incentive such as levy exemption based on the percentage of IBS usage in a project.. The government is taking the leading role in persuading the construction industry to adopt a more systematic approach and methodology in construction. The effort, started in 1998, is a strategic change in the construction industry.

If IBS is adopted, efficient, clean, safe and innovative are some of the new attributes that will be associated with the construction industry. With these outstanding features, plus attributes such as professionally managed and handled, workers with relevant skills, proper coordination and management as well quality will inevitably make IBS an excellent option for those involved in the industry to become global industry players in the international arena that demands high quality, efficient and professional services.

5.0 Conclusion

Survey on IBS system has been conducted through out Malaysia in 1996. The purpose of this survey is to gather information on IBS buildings in Malaysia. Besides that, a visual inspection study was also conducted to observe of any problems related to IBS system.

IBS features potential construction system for the future with emphasis on quality, higher productivity and less labour intensive. Besides the aim of gradually reducing the dependency on foreign labour and saving the country's loss in foreign exchange, IBS provides the opportunity for the players in the construction industry to project a new image of the industry to be at par with other manufacturing-based industry such as the car and electronic industries.

The adoption of IBS promises to elevate every level of the construction industry to new heights and image of professionalism. Finally, IBS should be seen as the modern methods of construction where modern and systematic methods of design, production planning and mechanized methods of manufacturing and erection are applied.

6.0 Acknowledgement

The authors would like to thank CIDB for providing grant on the survey study of IBS in Malaysia and UTM for allowing us to conduct the study.

7.0 Bibliography

[1] Peter C. Bruechle, 'Steel and Precast Concrete, the Way Forward', Master Builders Journal, 3rd quarter 2004.
[2] Kim S. Elliot, 'Off Site Prefabrication of Concrete Structures', Proceedings of the International Conference on Industrialised Building Systems IBS 2003, Kuala Lumpur, 10-11 September 2003.
[3] Larry Flynn, 'Framing the moment', Building Design & Construction, August 2001.
[4] Kim Elliot, 'Mixed options for Precast Concrete Construction', Building Design & Construction, July/August 2003.

EFFECTS OF DELAY TIMES ON PRODUCTION RATES IN CONSTRUCTION

By John Christian[1] and Daniel Hachey[2]

ABSTRACT: Factors that can be fairly easily identified and modified and can lead to significant improvements in production rates for activities in construction are considered in this paper. These factors are divided into four work categories. Two of the four work categories in which each construction activity was subdivided were idle and waiting times. Productivity measurements generally do not distinguish between the idle and waiting times. Conclusions can therefore be misleading, and more importantly, the attention of management is only vaguely and imprecisely directed to the cause of the inefficiencies. The breakdown of nonproductive time into two factors is therefore very important in directing the attention of management to the root causes of inefficient time. The variation in production rates used by contractors' estimators are given and compared with actual on-site production rates. The frequency of different sources of information used by contractors when estimating production rates, and the percentage use of production monitoring methods, are also given. A prototype expert system, using the Personal Consultant Plus shell program of 1987, was developed to assist in the acquisition and management of knowledge and data for the estimation of production rates.

INTRODUCTION

Productivity is extremely important in the construction industry. Governments and other owners are investing significantly less money into capital works and preventative maintenance programs, even though these programs would help curb the deterioration of the infrastructure. One of the reasons for this lack of financial commitment towards construction projects is that productivity and quality in the construction industry has not improved as much as in other industries, and construction is therefore regarded as a poor investment.

There are many factors that influence productivity in the construction industry. Some factors that create variations in production rates for certain activities are extremely difficult to control. There are other factors, however, that can be fairly easily identified and modified and can lead to significant improvements in production rates for activities. Some of these factors are determined and discussed in this paper.

Determining what these factors might be was the premise of Frederick W. Taylor's preliminary research in optimizing worker performance during the early 1900s. Taylor is most noted for the research he conducted in 1911 at Midvale Steel Inc. in Pennsylvania (Robbins 1986). By analyzing with stopwatch studies the efforts of a worker to load pig iron onto a railroad car, Taylor was able to show how the daily output per worker could be increased.

The success of Taylor's research inspired many others to study and develop new techniques of monitoring productivity by scientific means. For instance, Thomas has analyzed lost productivity at a construction site due to inefficient material management (Thomas and Sanvido 1989). Thomas's research work led to the development of an integrated material-management program that could be applicable to any construction site. The program consists of approximately 25 conditions or site factors that could have the potential to affect productivity on the construction site. The uniqueness of the program is that many of the factors are qualitative rather than quantitative. Factors such as disruptions, work content, constructability issues, construction methods, environmental conditions, and management aspects are just a few of the factors that are considered.

Thomas and Smith have further developed a more analytical approach for studying the mechanics of the problem (Smith et al. 1993). A productivity impact factor (PIF) has been developed that will allow more consistent comparisons to be made. This technique will therefore provide a means to gather a more homogeneous collation of information from a number of different sites. Consequently, this will permit useful comparisons of productivity from any number of construction sites used in further studies.

An international research project has been carried out by Handa and Thomas (1993) to standardize the measurement of construction labor productivity in some activities. The results of this research will obviate any disparities due to jobsite uniqueness and job complexity. The

[1]M.P. Gillin Chair, Constr. Engrg. and Mgmt., Univ. of New Brunswick, Fredericton, NB, Canada E3B 5A3.
[2]Grad. Student, Dept. of Civ. Engrg., Univ. of New Brunswick, Fredericton, NB, Canada E3B 5A3.
Note. Discussion open until August 1, 1995. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on June 21, 1993. This paper is part of the *Journal of Construction Engineering and Management*, Vol. 121, No. 1, March, 1995. ©ASCE, ISSN 0733-9364/95/0001-0020–0026/$2.00 + $.25 per page. Paper No. 6376.

research described in this paper is indirectly linked to the focus of their research, but specifically examines the delay times of another construction activity—concrete placement.

Using similar scientific techniques, others have made notable contributions towards improvements in construction productivity. Olgesby et al. (1989), for instance, maintain that job satisfaction and worker productivity are related: an increase in either will have a positive influence on the other. To identify many of the influences that can affect worker productivity, Harris and McCaffer (1989) have utilized video recorded times studies to help recognize particular problems on site. Flow of men and materials, equipment utilization and balance, and safety and working conditions are examples of some of the problems affecting the progress of a worker that can be identified using this method. Similarly, a "foreman-delay survey" (FDS) that was developed by Tucker et al. (1982), was found to be useful as an effective low-cost method for determining the sources of delay not directly related to site worker productivity. Using the FDS, a foreperson is asked to identify sources of delay, length of delay, and the number of workers affected. A calculation of lost person hours is then made, giving a breakdown of lost productivity by category.

Collectively, these researchers and others have contributed useful knowledge that can be used to promote better construction practices in order to improve productivity. Their efforts have been recognized as an attempt to shape the construction industry so that cost efficient and more productive construction practices on jobsites will someday become the norm rather than the exception.

Part of the uniqueness of the research described in this paper is the distinction between idle and waiting times, which create delays in construction activities. This breakdown of nonproductive time enables the attention of management to focus onto the causes of inefficient time and create efficient procedures. Maintaining efficient procedures, however, is difficult because most construction projects are unique and are prone to nonstandard building practices. This usually means that there are many factors to be considered. Material delay, management constraints, and adverse weather conditions are just a few of the factors that can affect the progress of an activity. To identify these and other factors that are not generally considered requires that the activity be monitored. The monitoring and measurement of the production rate of an activity then creates an effective means of showing where the progress of the activity can be improved. For the research described in this paper, a video camcorder was used to record concrete-placement activities at job sites in the Fredericton, New Brunswick, area in Canada.

To determine which factors adversely affected production, each activity was divided into four work categories: (1) Essential; (2) essential contributory; (3) idle; and (4) waiting. By noting whether lost productivity was due to "waiting" or "idle" time, it was recognized that many of the factors that affected an activity's progress (e.g., factors causing waiting time) could be rectified or improved by a response from management. Site managers with information on factors that created inefficiencies would therefore have a better ability to organize workers to achieve better production rates in the future.

Variation in Production Rates

Construction projects are generally unique and are built on sites with different work crews associated with different trades. The work is cyclical due to the weather, seasonal variations, and the economic climate. These factors affect production rates, and although there are many worthwhile measures that can prevent or reduce a loss in productivity, there are certain elements that cannot be eliminated to improve productivity. There are, however, many other factors that influence productivity that can be improved. It is these other factors that are identified and discussed in this paper.

Many of these factors can cause production rates for a given activity to vary considerably. To help understand why these variances occur, a questionnaire was sent to various construction companies in Eastern Canada requesting information concerning the production rates that they use in estimating and scheduling. The production rates for certain activities, shown in Table 1, are derived from 15 responses to the questionnaire. The wide range of production rates given in the table illustrates how difficult it is to estimate a particular production rate for any activity. The determination of the value of these rates is complex because productivity is difficult to analyze, and even if it is analyzed, the knowledge and data acquired are difficult and time consuming to interpret and evaluate.

When further clarification of the knowledge acquired was sought from respondents, it was discovered that some of the production rates, shown in Table 1, were modified later in the preparation of the estimate to reflect delay times and other time-consuming aspects of an activity. A strict comparison of each numerical value of the production rates should therefore be viewed with some caution.

In most construction companies the production rates are usually established by a combination of experts' opinions and the use of handbooks that contain productivity data. Although this data is often broken down to account for factors that significantly affect the production rates, little data and knowledge are acquired and stored for future use concerning the reasons for major reductions in productivity, such as waiting time.

TABLE 1. Estimated Production Rates Used by Contractors

Source of information (1)	ESTIMATED PRODUCTION RATES (m^3/person-h)					
	Reinforced Footings		Reinforced Foundation Wall		Reinforced Slab on Grade	
	Pumped (2)	Chute (3)	Pumped (4)	Chute (5)	Pumped (6)	Chute (7)
A	1.47	1.37	2.67	1.77	1.00	1.50
B	1.25	1.22	2.49	2.00	1.00	1.62
C	1.12	1.04	2.61	1.63	0.75	1.35
D	0.28	0.33	0.58	0.48	0.30	0.45
E	1.96	1.76	3.48	2.36	1.20	1.73
F	0.98	1.04	2.61	0.38	1.00	1.05
G	0.84	1.43	2.49	1.71	1.05	1.88
H	0.98	1.50	2.61	1.63	1.10	1.95
I	1.75	1.11	2.61	2.13	1.08	1.73
J	1.19	1.53	2.55	1.62	0.95	1.20
K	1.68	1.43	3.34	2.09	0.85	1.13
L	1.65	1.14	3.39	2.28	0.90	1.22
M	2.03	1.04	3.34	2.09	1.20	1.13
N	1.61	1.20	3.16	2.20	1.08	1.65
P	2.10	1.95	2.90	2.47	2.50	3.00
Average rate	1.39	1.27	2.72	1.79	1.06	1.51
Standard deviation	0.51	0.38	0.70	0.62	0.45	0.57

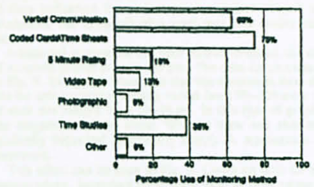


FIG. 1. Methods Employed to Monitor Productivity

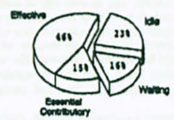


FIG. 2. Basic Time Components Used for Describing Effectiveness of Construction Worker

Although all construction projects are different, most construction activities have common parameters. For example, the concreting activity for a foundation wall involves delivery, placement, vibration, and finishing work. These basic steps are fairly consistent with this type of activity, no matter where, when, and how the concrete is being placed. However, variations in actual production rates among various sites are common. These variations, when analyzed, were found to be primarily caused by waiting and idle times.

In concreting activities it was found that the most significant reduction in the production rate was due to delays in the delivery of concrete to the site. This type of delay was often attributed to unexpected occurrences that appeared to be unrectifiable, and therefore was of secondary concern to a very busy management team.

Monitoring Productivity

Fig. 1 shows the various methods that are used by contractors to monitor progress on projects. The percentage use of each monitoring method by companies who responded to the questionnaire is given. Some of these methods capture the very important information concerning waiting time, but some do not. The two most effective methods are in the use of video tapes and time studies, because although many methods that are used can indicate the percentage efficiency, few methods are able to show where the root causes occur. It can be seen that, apart from two methods—verbal communication and time sheets that do not indicate efficiency, the percentage use of any method to monitor progress is less than 40%.

Acquisition and Measurement of Data and Knowledge

Seven construction sites in one city (Fredericton, New Brunswick, Canada) were monitored so that the factors affecting concrete placement operations could be determined. A total of 32 concrete-placement operations were recorded from these seven sites. The methods used to monitor these activities were video recording and stopwatch studies. Before the activity could be analyzed, it was subdivided into the four work categories: (1) Effective; (2) essential contributory; (3) waiting; and (4) idle. Effective work positively influences the progress of the activity, and work that has an indirect but positive influence on progress, such as the movement of materials or equipment for essential purposes, is considered essential contributory. Idle time represents a category in which the work could, but did not, progress, because the worker was not working. However, if a worker is unable to perform a task because of an uncontrollable external delay, such as late concrete delivery, then the lost time is considered waiting time, not idle time. This procedure was the method used to calculate the production rates published by Christian and Hachey (1992) (see Table 2).

Fig. 2 shows how a worker's time can be divided into the four work categories. Information presented in this fashion emphasizes the inefficient factors that affect the progress of a worker that may not be apparent during normal observations. This information permits management to clearly identify inefficient factors that are revealed during analysis, and therefore utilize a worker's time more effectively.

The information obtained from the answers given in the questionnaire was further enhanced by knowledge obtained from experts and practitioners in the field. By conducting interviews with site personnel while field recordings and measurements were being performed, heuristic knowledge was gradually gathered. If the expert being interviewed referred to supervisors or colleagues from previous projects who were more familiar with certain aspects, then these persons were often contacted for further knowledge acquisition.

To help explain features of an activity that were not apparent from the video analysis, interviews were repeated again with some experts. The various sources used for the gradual progression of knowledge and data elicitation and acquisition, are shown in Fig. 3.

A prototype expert system was developed to handle and store the knowledge and data from all of the sources of intelligence, and also to create a decision support system that would enable a user, through a simple question and answer routine, to obtain a much more accurate estimate of the probable production rate.

The fairly simple prototype system leads the user to an estimate of the production rate that depends upon the answers that are given in the questions posed. The answers were used as a link to the knowledge and databases. In this particular system, the cumulative knowledge and

TABLE 2. Sample of Production Rates Measured at Various Project Sites

Location/site (1)	Crew size (persons) (2)	Method of placement (3)	Volume concrete placed (m^3) (4)	Activity duration (min) (5)	Delay (min) (6)	Production rate (m^3/person-h)	
						Average (7)	Modified (8)
1 B	3	chute	5	75	20	1.33	1.82
2 A	3	chute	7.8	73	46	2.14	5.78
3 A	4	chute	4	43	15	1.40	2.14
4 A	4	chute	5	57	9	1.31	1.56
5 A	4	chute	5.5	105	49	0.79	1.47
6 C	4	chute	12	94	6	1.91	2.06
7 C	4	chute	16	140	5	1.71	1.78
8 A	5	pump	19	124	28	1.84	2.37
9 A	5	pump	32	154	50	2.49	3.69
10 A	7	pump	24	185	78	1.11	1.92
11 D	7	pump	27.5	98	18	2.41	2.94

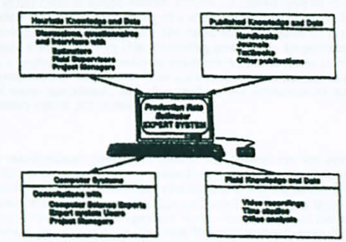


FIG. 3. Knowledge and Data Elicitation for Expert System

database were derived not only from many experts, but also from the knowledge and data gathered in the field.

Providing such a wide array of knowledge permits the user to make reasonable assumptions on worker density, learning rate, weather conditions, crew experience, potential delays, and other relevant factors affecting the progress of an activity. Using these parameters to help estimate the production rate for an activity therefore provides a more realistic prediction of what the rate should be for that particular jobsite.

Analysis of Data

A comparative analysis of production rates from the various sites was possible because most construction activities have common parameters. For example, as mentioned earlier, the concrete operation for a foundation wall requires delivery, placement, vibration, and finishing work. In spite of these common parameters, it was found, not surprisingly, that there were differences in production rates between the various sites. These differences were found to be caused mainly by the waiting and idle times.

Several control parameters were identified prior to the collection of the data. This was done to ensure that each site and each project contained the same parameters for the purposes of comparative analyses. The following parameters were selected: (1) The construction of commercial buildings; (2) the application of similar equipment and methods; (3) the same general location (Fredericton, New Brunswick), (4) the same type of construction contract; and (5) a nonunionized labor force.

Information obtained from the site video recordings was analyzed so that inefficiencies reducing the productivity of a worker could be revealed. One such analysis was the categorization of time utilization for each separate worker at each site. The proportion of time spent on productive and nonproductive work was thus evaluated for each worker. Fig. 4 shows typical data.

Additional analysis of the information involved the determination of the rate of the volume of concrete placed at each job site. The data for this analysis were plotted on a graph, as shown in Fig. 5. The graph illustrates that the maximum time duration for concrete placement at each site for this particular sample varied from 90–135 min, and that the volume of concrete placed at each site ranged from 10–16 m³. In this type of graph, the crew efficiency is represented by the magnitude of the slope. When a crew was able to work uninterrupted, their work rate gradually improved (increasing slope). A momentum was therefore built up, and efficiency improved.

This effect can be seen in Fig. 5. Crews on sites C6 and C7, which did not experience work interruptions, improved their work rate as time passed. The slope of the graphs of quantity against time increased. However, crews at sites E12 and E13, which did experience a work interruption, did not improve their work rate as time passed, and therefore did not produce an increasing slope of quantity against time.

Idle and Waiting Times

Many of the measurements of production rates revealed that waiting time delays were an extremely significant part of reduced productivity. Fig. 4 clearly shows this problem. A measure of how inefficiencies reduce productivity is the labor utilization factor (LUF). The LUF categorizes the amount of effective, essential contributory, and idle work performed by a tradesperson during a particular construction activity. This measurement is sometimes used as a guide to determine if a crew has performed work efficiently. However, the labor utilization factor does not generally distinguish between the idle and waiting times. Conclusions can therefore be misleading, and more importantly, the attention of management is only vaguely and imprecisely directed to the cause of the inefficiencies. The breakdown on nonproductive time into

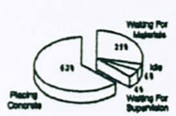


FIG. 4. Time Utilization for Typical Concrete Worker

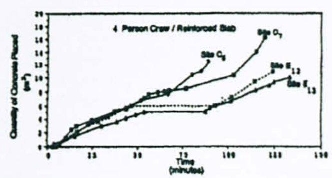


FIG. 5. Effects of Crew Momentum on Concrete Placement Operations

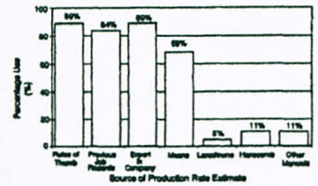


FIG. 6. Sources of Information when Estimating Production Rates

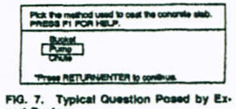


FIG. 7. Typical Question Posed by Expert System

TABLE 3. Average Production Rates

Method (1)	AVERAGE PRODUCTION RATES (m³/person-h)					
	Reinforced Footings		Reinforced Foundation Wall		Reinforced Slab on Grade	
	Pumped (2)	Chute (3)	Pumped (4)	Chute (5)	Pumped (6)	Chute (7)
Used by estimators	1.40	1.30	2.90	1.90	1.00	1.50
Measured in field	1.39	1.27	2.72	1.79	1.06	1.51

two factors, the idle and waiting times (Fig. 2), is therefore very important in order to direct the attention of management to the root cause of the nonproductive time.

Production Rate Estimates

The different sources for estimating production rates that are used in construction offices are shown in Fig. 6. Few of the sources contain information and knowledge derived from previous projects, and therefore a reduction in productivity due to waiting time is not adequately addressed in practice. Although there appears to be substantial agreement between the average actual production rates measured in the field and the overall average of those rates used by estimators (Table 3), there are few data available that enable the contractor to determine where the significant inefficiencies occurred. This, of course, means that there is no system to improve the inefficiencies on future projects.

The prototype expert system was developed to assist in the acquisition and evaluation of knowledge and data for the estimation of production rates. Personal Consultant Plus was the shell program used to construct the rules in the expert system. This computer-aided decision support system helps estimators to calculate production rates more accurately by prompting users to consider factors that will make production rates vary, and to show where and why inefficiencies might occur. The system will alleviate the current problem of production rates often being estimated by less-experienced personnel in contractors' organizations.

The system will allow an estimator an alternative method for estimating production rates. It simulates a consultation between the computer, as the knowledge and data source, and the user, who answers certain questions when prompted. The questions and answers formulated were compiled from the knowledge acquired from field analyses and from experts' opinions. Responses to the questions are in the form of single valued, ask-all, or yes/no type of format. For instance, the format of a question relating to the casting of a concrete slab is shown in Fig. 7. By choosing "pump" as the technique employed to place the concrete, as shown in Fig. 7, a link is then established to questions associated with this concreting procedure. Depending on how the questions are answered, a probable, more realistic production rate is given to the user, which will reflect conditions specified for the jobsite. The system therefore utilizes the equivalent cumulative knowledge of many specialists, and also enables the estimator to use production rates that more closely reflect actual job conditions.

CONCLUSIONS

The attention of management personnel should be focused on the sources and causes of delays. A major problem at present is that several methods that measure and monitor productivity on construction sites are unable to direct attention to the cause of the delay. The breakdown of nonproductive time into two factors, the idle and waiting times, is therefore very important in order to direct the attention of management to the root causes of the nonproductive time. For instance, the delays associated with "waiting for supervision" were found to be very considerable. The managers on a construction site (the project manager, the construction engineer, the superintendent/foreperson), however, often have severe time constraints and problems with time management.

This leads on to an obvious conclusion. During the estimating stage of a project, an insufficient number of supervisors and managers are generally allocated to the construction site, because of budgetary problems. The resulting lack of sufficient supervision on the site, however, generally lowers productivity, and therefore increases overall project cost. Consequently, an increase rather than a decrease in site supervision is needed in order to help reduce the overall cost of a project.

The use of an expert system to predict production rates will enable contractors to capture and retain specific knowledge and data from past projects and use them as a support system for future projects under consideration. The prototype model provides the user with probable production rates for specific activities for given circumstances. The system will enable contractors to not only predict more realistic production rates but also to provide a list of possible delays, and instructions on what might be done to prevent them from occurring. It will also allow contractors to utilize their project manager's time more effectively by allowing them to access the necessary information required to estimate the production rate of an activity more quickly.

APPENDIX. REFERENCES

Christian, J., and Hachey, D. (1992). "Production rates in construction." *Proc., Conf.*, Can. Soc. for Civ. Engrg., Quebec City, Quebec, Canada.

Handa, V. K., and Thomas, H. R. (1993). "International study on construction site productivity." *CIB W-65 Symp. 93*, Nat. Tech. Information Service, Springfield, Va., Vol. 2, 999–1002.

Harris, F., and McCaffer, R. (1989). *Modern construction management*. BSP Professional Books, Osney Mead, Oxford, England, 68–73.

Oglesby, C., Parker, H., and Howe, G. (1989). *Productivity improvement in construction*. McGraw-Hill Book Co., Inc., New York, N.Y.

Personal Consultant Plus. (1987). *Reference guide manual*. Texas Instruments, Austin, Tex.

Robbins, S., and Stuart-Kotze, R. (1986). *Management concepts and practices*. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Smith, G., Shumway, J., and Thomas, H. R. (1993). "Productivity influence factors for baseline comparisons." *CIB W-65 Symp. 93*, Trinidad, (2), 989–997.

Thomas, H. R., and Sanvido, V. (1989). "Impact of material management on productivity—a case study." *J. Constr. Engrg. and Mgmt.*, ASCE, 1(115), 370–384.

Tucker, R., Roggie, D., Hayes, W., and Hendrickson, F. (1982). "Implementation of foreman delay surveys." *J. Constr. Div.*, ASCE, 4(108), 577–591.